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SCIENCE AMONG THE CHINESE

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I. Introduction

(*a*) *Chinese Science a Case of Arrested Development.*—In scientific knowledge, as in nearly everything else, China presents a case of arrested development. Chinese conceptions regarding the body of man, the materials of the earth's crust, the surface forms of our globe, of its origin and process of formation, of the vast celestial universe through which it whirls, of the nature and origin of matter and of cosmogony in general, are the conceptions characteristic of western peoples before and during the middle ages. Not only so, but they are the same as were held by her own sages centuries before that period; in many cases they express the best thought of China's deep thinkers in the days of Pythagoras and perhaps prior to his time, while in others they give us the cream of Chinese philosophy as developed during the early days of the glorious Sung dynasty (A.D. 1020–1120). While of course those who have within the last few decades read the books of the west have modified their previous notions, the number of such as compared with the general people, though rapidly increasing, is still small and the purely Chinese conceptions of anatomy, physiology and medicine still consist of interacting functions of hypothetical organs, the intermixings of various vital fluids, and the subtle influence of capricious humors; chemistry is still alchemy; geography, mere guesswork; geology, vague mythology; astronomy, astrology; and exact physical science, nil. Science in China has made few advances during the last few centuries and is now but slowly responding to a new impulse from abroad in all its departments.

(*b*) *Their Inventions, Arts, Engineering, not Evidence of Scientific Attainment.*—To be sure, several striking inventions are probably to

the credit of the Chinese—gunpowder, printing, mariner's compass, paper, etc., but the original crude forms or methods were not improved. Their use among the Chinese apparently had no direct effect in promoting their development among western peoples, and in nearly every case the invention was founded on the specific properties of matter discoverable directly and did not involve any scientific concept of principle established and tested by observation. It would seem too that much of the Chinese servile imitation in mechanics, metallurgy and other arts is due to ignorance of the real nature of the materials they use, and yet it is not for long that such things have been intimately known to ourselves of the west. The Chinese have made little progress in investigating the principles of mechanics, but have, however, practically understood most of the common mechanical advantages involved in various simple appliances. The lever, wheel and axle, cog wheels, wedge and rack and pinion, have long been known, but the screw is not frequent. In many of their contrivances there is an excessive expenditure of human strength; in many the object is merely to give a direction to this strength, not to decrease it, as in their manner of carrying a heavy stone, instead of constructing a simple truck that would transport it with half the expense of human power; yet the use of a truck would require something more in the way of good roads than most parts of China can boast of, and again human labor is almost the cheapest thing in China.

While it is true that the manufactures of silk, of porcelain and of lacquered-ware were original with the Chinese, and that in none of these have foreigners yet succeeded in fully equalling the native product, and while the French looms are practically the same as those in Canton, except that steam power takes the place of human feet, it is also true that the mechanical arts and implements of the Chinese have a simplicity which suggests that the faculty of invention died with the initiator.

Three accomplishments in Chinese engineering, however, challenge the rest of the world to show similar feats in any remote time. The Great Wall, traversing high mountains and large rivers, built two hundred years before the Christian era, still stands as the most extensive monument of antiquity to attest the high engineering skill and kingly energy of that day. Of like herculean proportions and for a more useful purpose is the Grand Canal which up to the date of its construction was the greatest public commercial work ever undertaken. The Great Sea Wall along the north shore of Hangchow Bay, judged in the light of the tremendous difficulties involved in its construction merits even greater praise for native energy and skill.[1] And yet the very present

[1] See "A Visit to the Hangchow Bore," THE POPULAR SCIENCE MONTHLY, February and March, 1908.

condition of the Grand Canal, which has doubtless been its condition for a century or more, is an eloquent witness to arrested development due to failure to apply hydraulic improvements.

While giving due credit for what they have done, we feel justified in concluding that the arts and the inventions of the Chinese do not, after all, witness to any degree of scientific attainment among them. Many of the later modern inventions of western people are the result of applied science, which certainly was not the case with these early inventions of the Chinese. There seems, however, to be room for a difference of opinion even among authorities. In 1839 G. T. Lay asserted in writing about Chinese musical instruments:

> It has been declared that the Chinese have no science, but of a surety, if we advance in the free and scholar-like spirit of antiquarian research, we shall be obliged to set our feet upon the head of this assertion at every step in our progress.

And yet in his authoritative work, Williams closes his rather compendious account of "Science among the Chinese" with this summary:

> On the whole it may be said that in all departments of learning the Chinese are unscientific; and that while they have collected a great variety of facts, invented many arts, and brought a few to a high degree of excellence, they have never pursued a single subject in a way calculated to lead them to a right understanding of it, or reached a proper classification of the information they possessed relating to it.

It may be of interest then to notice some of the leading ideas in what we may call "Chinese science" and to inquire into the causes of China's scientific backwardness as compared with modern western knowledge. In doing this we shall be largely indebted to Williams's "Middle Kingdom" for many of our facts and to Martin's "Lore of Cathay" for suggestive lines of thought.

II. The Content of "Chinese Science"

1. *Anatomy.*—Wylie has noted fifty-nine Chinese treaties in medicine and physiology (some of them belonging to the earliest days), many of which contain good sense and sound advice amid the strangest theories. Harland has lucidly and in detail described the Chinese ideas (apart from the gradually spreading foreign teaching) concerning the organization of the body and the functions of the chief viscera—false ideas which a very little dissection, a prohibited practise, would have banished. We shall not pause to consider these, but merely note that the most curious is perhaps their idea of the liver, which they place on the right side of the body.

> It has seven lobes; the soul resides in it; and schemes emanate from it; the gall-bladder is below and projects upward into it, and when the person is angry it ascends; courage dwells in it; hence the Chinese sometimes procure the gall-

bladder of tigers or bears, and even of men, especially notorious bandits executed for their daring crimes, and drink the bile, with the belief that it will impart courage.

Theories are numerous to account for the nourishment of the body and the functions of the viscera, and upon their harmonious connection with each other and the five metals, colors, tastes and planets is founded the well-being of the system, the whole intimately connected with the all-pervading functions of the *yin* and *yang*—those universal solvents in Chinese philosophy.

2. *Materia Medica, Botany and Zoology.*—The advance made by the Chinese themselves in the study of natural history is shown by the contents of the two chief works—"Pun Tsao," or "Herbal," compiled by Li Shi Chin after thirty years spent in collecting information, published about 1590 (40 octavo volumes—52 chapters), and "Chih Wah Ming-shih Tu-kao," or "Researches into the Names and Virtues of Plants," 60 volumes with plates, some of them good drawings, published in 1848.

The author of the first of these treatises was the first and last purely native critical writer on natural science. He consulted some eight hundred previous authors and selected fifteen hundred and eighteen prescriptions, to which he added three hundred and seventy-four new ones, arranging the whole in what for his day was a scientific manner.

After two introductory chapters on the practise of medicine and an index to the recipes contained in the work, which fills the first seven volumes, there are two chapters (filling three and a half volumes), giving a list of medicines for the cure of all diseases, and this with an essay on the pulse in the final volume constitutes the therapeutical section of the treatise. The remaining forty-eight chapters cover, after the fashion of the author, the whole range of natural objects—treating of inorganic substances under "water" and "fire" and minerals, as earth, metals, gems and stones, throwing into a polyglot chapter what could not be included in the preceding sections; the vegetable kingdom is presented under the five divisions—herbs, grains, vegetables, fruits and trees; these again into families containing members which have no real relationship to each other, the lowest term sometimes being a genus, a species, or even a variety, as Linnæus used these terms.

In the classification of the minerals, etc., the influence of the language itself is shown, for, as pointed out by Williams, the division is exactly that of the seven radicals which stand for fire, water, earth, metals, gems, stones and salts, under which the names of inorganic substances were classified in the imperial dictionary. The same thing is true for other parts of the treatise.

In classifying herbs, the habitat is taken as the criterion, an "herb" denoting whatever is not eaten or used in the arts or which does not attain to the magnitude of a tree.

The zoological grouping is as crude and unscientific as that of plants, though the sixteen zoological characters in the language are not so far astray from being true types of classes as the eleven botanical ones, and these groups, though containing many anomalies, are still sufficiently natural to teach those who write the language something of the world around them.

The properties of the objects spoken of are discussed in a very methodical manner, so that a student can immediately turn to a plant or mineral and ascertain its virtues.

3. *Geography.*—A few sentences from Williams's "Middle Kingdom" will show the state of geographical knowledge among the Chinese prior to western influence.

> Their geographical knowledge is ridiculous. Maps of their own territories are tolerably good, being originally drawn from actual surveys made by nine of the Jesuits, between 1708 and 1718, and since that time have been filled up and changed to conform to alterations and divisions. Before the day of western influence, and even long after, to a great extent until the present decade, in fact, the Chinese did not teach geography in their schools, even of their own empire. The common people have no knowledge, therefore, of the form and divisions of the globe, and the size and position of the kingdoms of the earth. Their common maps delineate them very erroneously, scattering islands, kingdoms and continents, as they have heard of their existence at haphazard and in various corners beyond the frontiers. . . . Their notions of the earth's inhabitants are equally whimsical. . . . Charts for the guidance of the navigator, or instruments to aid him in determining his position at sea, the Chinese are nearly or quite destitute of; they have retrograded rather than progressed in navigation, if one judges from the accounts of their former trade with ports in the Persian Gulf, on the Malabar coast, and in the Archipelago.

Of course in the modern schools now under way throughout the empire correct geographical notions are being taught; but such schools have been so few up till 1900 and the total number of modern students so small even since then, that the notions of the common people are still subject to Williams's characterization. To what extent even the supposedly more intelligent are still "at sea" in such matters is well shown by two recent cases, which illustrate also some effects of present-day scientific ideas upon Chinese minds educated according to the methods which have prevailed in China for ages.

At the Shansi University, in discussing the search for the North Pole, a holder of the Chinese first degree seriously suggested that when the ship had proceeded as far north as possible, the pole might be seen with the aid of a telescope. Another man thought of the same expedient, but considered that the curvature of the earth would render it impossible, and suggested that ascending in a balloon might afford the opportunity to use the telescope to see the pole. Still another man thought it would be simpler first to moderate the climate of the polar regions by planting trees along the way there, and by diverting the gulf

stream in that direction to render possible a closer approach to the Pole.

Another graduate of the ancient system in Canton offered the following as an explanation of why he thought it was hotter in Peking than in Canton:

"At Peking the earth is thicker than at Canton, and so a person living on top of the earth is nearer the sun at Peking than at Canton and hence gets more heat, and we know that the earth is thicker at Peking than at Canton because in Peking you have to dig many tens of feet to get water, whereas in Canton you can readily strike water at ten to twenty feet."

4. *Astronomy—Astrology.*—The precise attainments of the ancient Chinese in astronomy are not easily understood from the scanty records. To the burning of all native scientific books, except those on agriculture, medicine and astrology, by imperial order in 221 B.C., the Chinese attribute the loss of a mass of astronomical learning. Wylie furnishes a list of 925 solar and 574 lunar eclipses, extracted from Chinese works, observed between 2150 B.C and A.D. 1785. The earliest known record of an eclipse occurs, though imperfectly, in the ancient "Shu-King," or "Book of History." Retrospective calculation shows that it may have occurred as early as the autumn of 2158 B.C. Simple methods for predicting solar eclipses seem to have been in use in China before 2000 B.C., but this eclipse of 2158 B.C. is said to have appeared unexpectedly and to have so disturbed the emperor that he at once executed the two court astronomers for failing to predict it!

In the Chinese canonical books thirty-eight solar eclipses are mentioned, eighteen of which agree with modern lists, but the others seem in error in either month or year, though the day is always correct. This suggests that the records are reliable and that the non-agreement is probably due to an imperfect knowledge of the ancient calendar, particularly with reference to intercalation and the beginning of the year, which are probably irregular. Intercalations were probably introduced by Yao about 2637 B.C., but it is hardly likely that they have continued without variation to this day. Romish missionaries rectified the calendar about 1700 and have aided in its preparation until recently. A cycle of sixty years was adopted in very early times, but there is no record of when or why this number was selected. The Chinese year is lunar, but its commencement is regulated by the sun. New Year falls on the first new moon after the sun enters Aquarius, which makes it come not before January 21 nor after February 19.

Comets, whose brilliancy enabled them to be seen, have been carefully noted by the Chinese, because their course among the stars is thought to determine their influence as portents. A list of 373 comets mentioned in Chinese records has been published, extending from 611

B.C. to A.D 1621. The general value of these records is thought to entitle them to credence.

While these observations of eclipses and comets were made for astrological and state purposes, they are not without value to European astronomers and chronologists. It would not be entirely safe to judge of the astronomical attainments of the Chinese from what has come down to our day, or by present popular notions. The knowledge contained in their own scientific books has not been taught, and in general the astronomical ideas of the Chinese are vague and inaccurate and serve as the basis of superstitious astrology rather than as an agency of enlightenment among the people. The writer vividly recalls his experience during a recent lunar eclipse, when almost the entire population of one of the largest cities on the Yangtsze turned out, each one carrying something with which to make a noise, kettles, pans, sticks, drums, gongs, fire-crackers, etc., to aid in frightening away the dragon of the sky from his hideous feast. And even the crew of a Chinese man-of-war, foreign built and armed with Krupp guns, will by orders published in *The Peking Gazette* turn out with drums, iron pans, etc., to make a din to "save the moon.'

Chinese astronomers distinguished five planets, or "moving stars," and named them according to their ideas of elementary substances: Venus, Golden; Jupiter, Wooden; Mercury, Water; Mars, Fire; Saturn, Soil. To them the galaxy was The Heavenly River, a close analogy to our term, The Milky Way. It is interesting to note how descriptive the Chinese terms are as applied in translations of modern astronomical ideas—a nebula is a "star-mist"; asteroids are "small moving stars"; the spectroscope is the "shooting shadow-lamp"; and spectrum analysis is "the shooting-shadow-difference-telling-light-method."

5. *Mathematics.*—The arithmetical notation of the Chinese is based on the decimal principle, but as their figures are not changed in value by position, it is difficult to write out clearly the several steps in solving a problem. Arithmetical calculations are performed with a "counting board," an arrangement of balls on wires, which can, however, only serve as an index for the progress and result of a calculation done in the head, so that if an error is made, the whole operation must be done again.

The study of arithmetic has attracted attention among the Chinese from early times, and notices found in historical works indicate some treaties extant even in the Han dynasty (206 B.C–A.D. 214), followed by a great number of general and particular works down to the Sung Dynasty (1020–1120 A.D.). The Hindu processes in algebra were known to Chinese mathematicians, but though studied even after intercourse between the countries had ceased, these branches made slow progress down to the end of the Ming Dynasty (A.D. 1368–1644).

The mathematical writings of the early Romist missionaries greatly improved the mathematical texts available in Chinese, and since foreigners have begun to introduce western science, the development has been rapid. But aside from the graduates from modern schools, the knowledge of mathematics even among the learned men of China is very small, and the common people study it only as far as their business requires, and that is exceedingly little. The cumbersome notation and the little aid which such studies gave in the ancient system of literary examinations (only abolished in 1905) doubtless discouraged the pursuit of what they seem to have no taste for as a people. Chinese authors acknowledge the superiority of western mathematicians, and generally ascribe their advance in the exact sciences to this power.

6. *Action and Reaction of Elements.*—Williams in his "Middle Kingdom" gives a table showing the leading "elementary" correspondencies in the curious speculations used by Chinese philosophers to account for any possible contingency in the changes of the visible universe, which in the hands of geomancers and fortune-tellers are the bases of considerable imposition on the people. The five elementary powers or *hing* are: water, fire, wood, metal and earth, and the table gives the qualities, tastes, and activities of the five *hing* as correlated with five points of the compass (the fifth being "center"), the five corresponding planets, five colors, five viscera, five musical notes, five early emperors, four seasons, and four quarters of the zodiac. But to consider these ideas in detail would lead too far afield into unprofitable vagaries.

7. *Chemistry—Alchemy.*—Chemistry and metallurgy have been unknown as sciences, but many operations in them are performed with a considerable degree of success, and bear testimony to Chinese shrewdness and ingenuity in the existing state of their knowledge. The skill which they exhibit in metallurgy, their brilliant dye-stuffs and numerous pigments; their early knowledge of gunpowder, alcohol, arsenic, Glauber's salt, calomel and corrosive sublimate; their pyrotechny; their asphyxiating and anesthetic compounds—all give evidence of no contemptible proficiency in practical chemistry. In their books of curious recipes (see section 2) are instructions for the manufacture of sympathetic inks, for removing stains, alloying metals, counterfeiting gold, whitening copper, overlaying the baser with the precious metals, etc., many of the rules in which are still in common use, and bear in their very terms the stamp of an alchemic origin. Dr. Martin in his "Lore of Cathay" presents striking evidence to show that in all probability western alchemy, from which our modern chemistry has come, had its root in the art as practised in China, where it appeared as an indigenous product, coeval with the dawn of letters.

One doctrine of Taoism which was developed six centuries before Christ regards the soul and body as identical in substance, and main-

tains the possibility of preventing their dissolution by a course of physical discipline—a seed-thought which led the disciples of Laotze to investigate the specific properties of matter in the two-fold search for long life and riches. In studying both the vegetable and mineral kingdoms Chinese alchemists were guided by the supposed analogy of man to material nature, which led them to ascribe an essence or spirit not only to animals and plants, but to minerals as well, so that in their view matter itself was constantly passing the limits of sense and assuming the character of conscious spirit. Thus was the world filled with fairies and genii.

We need not discuss in detail the characteristic ideas of Chinese alchemy, but merely note that it had full vigor six centuries prior to western alchemy, which did not appear till A.D. 400 when intercourse was quite frequent between China and Byzantium, Alexandria and Bagdad. The two schools had much in common: same aims, closely corresponding properties ascribed to the two elixirs in each; principles, means, mystical character of nomenclature, and extravagant style of alchemic writings, all practically identical. So that, although it may be granted that the leading objects of alchemical pursuit might have occurred to men in any country as they felt their way towards a knowledge of nature, yet an independent origin seems unlikely, and it is almost certain that alchemy had its birth in the far east, yea in China, since the claims of India seem excluded by the abundant proof that the alchemy of China is not an exotic, but an indigenous product, the earliest forms of which are found in the "Book of Changes," a significant title, whose diagrams date back to 2800 B.C., the text to 1150 B.C., and the Confucian commentary thereon to 500 B.C. It is a striking fact that this book, chief in the canon of Taoism, was spared from the flames of the Tyrant of Ch'in to which all other writings of Confucius and his disciples were consigned.

8. *General Cosmological Ideas.*—Contrast the modern ideas of the age and origin of the earth and of the extent of the universe in time with the following conceptions of Chu Hi (Chu Fu Tsz), the most famous of the eleventh-century philosophers:

In the beginning heaven and earth were just the light and a dark air. This one air revolved, grinding around and around. When it ground quickly much sediment was compressed, which, having no means of exit, coagulated and formed the earth in the center. The subtle portion of the air then became heaven and the sun, moon and stars, which unceasingly revolve on the outside. The earth is in the center; it is not below the center.

Heaven revolving without ceasing, day and night also revolve, and hence the earth is exactly in the center. If heaven should stand still for one moment, then the earth must fall down; but heaven revolves quickly, and hence much sediment is coagulated in the center. The earth is in the sediment of the air; and hence it is said, the light, pure air became heaven, the heavy, muddy air became earth.

At the beginning of heaven and earth, before chaos was divided, I think there were only two things—fire and water—and the sediment of the water formed the earth. When one ascends a height and looks down, the crowd of hills resemble the waves of the sea in appearance; the water just flowed like this. I know not at what period it coagulated. At first it was very soft, but afterward coagulated and became hard. One asked whether it resembled sand thrown up by the tide? He replied, just so; the coarsest sediment of the water became earth and the purest portion of the fire became wind, thunder, lightning, sun and stars. . . . Before chaos was divided the *Yin-yang*, or light-dark, air was mixed up and dark, and when it divided the center formed an enormous and most brilliant opening, and the two principles were established. Shao Kang-tsieh considers one hundred and twenty-nine thousand six hundred years to be a *yuen*, or *kalpa;* then, before this period of one hundred and twenty-nine thousand six hundred years there was another opening and spreading out of the world; and before that again there was another like the present; so that motion and rest, light and darkness, have no beginning. . . .

There is nothing outside heaven and earth, and hence their form has limits, while their air has no limit. Because the air is extremely condensed, therefore it can support the earth; if it were not so, the earth would fall down.

Chu Hi's theory considers the world to be a plane surface—straight, square and large—measuring each way about 1,500 miles and bounded on the four sides by the four seas. The sun, moon and stars revolve around it at the uniform distance of 4,000 miles. Estimates of the long mythological periods antecedent to the appearance of Fuh-hi (the monarch of "highest antiquity," 2852 B.C., according to Chinese annals) vary from 45,000 to 500,000 years.

These ancient Chinese writings are a curious mixture of sense and nonsense, partially laying the foundation of a just argument and ending with a tremendous non-sequitur, apparently satisfactory to themselves, but showing pretty conclusively how little pains they took to gather facts and discuss their bearings. One thing is to be observed concerning them, which is characteristic to-day, viz., there is no hierarchy of gods brought in to rule and inhabit the world they made; no transfer of human love and hate, passions and hopes, to the powers above, as in the Greek or Egyptian mythology; all here is represented as moving on in quiet order, the work of disembodied agencies or principles. "There is no religion, no imagination; all is impassible, passionless, uninteresting."

Perhaps the most sensible and orderly account of the creation to be found in these writings is the following:

Heaven was formless, an utter chaos; the whole mass was nothing but confusion. Order was first produced in the pure ether, and out of it the universe came forth; the universe produced air and the air the milky way. When the pure male principle *yang* had been diluted, it formed the heavens; the heavy and thick parts coagulated and formed the earth. The refined particles united very soon, but the union of the thick and heavy went on slowly; therefore the heavens came into existence first and the earth afterward. From the subtle

essence of heaven and earth the dual principles *yin* and *yang* were formed; from their joint operation came the four seasons, and these putting forth their energies gave birth to all; they produced fire; and the finest parts of the fire formed the sun. The cold exhalations of the *yin* being likewise condensed, produced water; and the finest parts of the watery substance formed the moon. By the seminal influence of the sun and moon came the stars. Thus heaven was adorned with sun, moon and stars; the earth also received rain, rivers and dust.

But such explanations were too subtle for the common people, and they personified and deified the powers and operations, though with far less imaginative genius and fine taste than the Greeks displayed in the same line. The most striking legend is that of *Pwanku,* the first creature, who was "hatched" from chaos by the dual powers and who then chiseled the universe into form and order by the might of his hands. His efforts continued 18,000 years, and by degrees he and his handiwork increased:

The heavens rose, the earth spread out and thickened, and *Pwanku* grew in stature, six feet every day, till, his labors done, he died for the benefit of his handiwork. His head became mountains, his breath wind and clouds, and his voice thunder; his limbs were changed into the four poles, his veins into rivers, his sinews into the undulations of the earth's surface, and his flesh into fields; his beard, like Bernice's hair, was turned into stars, his skin and hair into herbs and trees, and his teeth, bones, and marrow into metals, rocks, and precious stones; his dropping sweat increased to rain, and lastly, the insects which stuck to his body were transformed into people!

It must be confessed that most of us will find this quite as clear and a far more interesting account of the universe than the learned disquisition of the famous Chu Fu Tsz.

(*To be concluded*)

WHY DO CERTAIN LIVING FORMS PRODUCE LIGHT?

By F. ALEX. McDERMOTT

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TO every observer of natural phenomena, the query must some time come, "Why do certain living creatures produce light?" The luminous molds of decaying wood, the photogenic bacteria of the sea-water, the fire-flies and lightning bugs, the deep-sea fish and other mysterious forms "that move in the waters"—why should some of them be endowed with the property of producing light? The question is undoubtedly one of fundamental biologic importance. The production of light by living forms is really no more wonderful than the production of heat, motion or electricity, but the production of heat and of motion is so common and so well known that but little attention is paid to them, while the forms which produce electricity are relatively so scarce that they are little known outside of the scientific world. Between these classes are the forms possessing the photogenic function—sufficiently common to be well known almost everywhere, and yet sufficiently scattered among the creatures of the earth to excite wonder and admiration at the novelty of the property. We can, of course, beg the question by replying, "These creatures have the power of producing within themselves some chemical substance which, under certain circumstances, produces light, probably as the result of oxidation," but this or equivalent statements leave us very little nearer satisfaction than at first.

The matter presents also another question which is difficult to answer: Why should one creature be endowed with the photogenic function, and yet some other form, closely related to the first, be unprovided therewith? Did all creatures originally possess the power to produce light and have all but the few we know lost this power, or have the few that possess photogenicity acquired the power as a result of the development of certain habits or conditions of life? It seems probable that both explanations may be advanced for different forms—*i. e.*, that in some cases related existing forms, some of which possess the photogenic function and others of which do not, are descended from a common photogenic ancestor, while in others the function has been developed during the history of the species.

There are certainly three reasons for the existence of the photogenic function some one of which is applicable to the great majority of luminous creatures above the unicellular and very lowly organized

forms. The first of these is that it is a secondary sexual character; the second, it is protective in purpose; third, it is a lure for prey. Other less general or less obvious uses may be shown, but in the great majority of cases one or the other of these explanations of the use of the light-producing function will be found adequate, and sometimes more than one will apply to a given species.

The simplest luminous forms are the bacteria. It is certainly difficult to see that photogenicity can be of any especial service to these unicellular organisms. Most, if not all, of the photogenic bacteria are of marine origin, and it is possible that some of them may be pathogenic to certain marine creatures when ingested, and the light thus serves to warn the bacterivorous plankton, etc., that these bacteria are dangerous food. Some species have been found to be pathogenic to Talitrus, a crustacean, which may serve as a case in point.

Luminous fungi are quite common, and here again we must leave the question with at most only a poor attempt at explanation. Protective or warning it may be; but the author has never heard of luminosity in the most poisonous of all fungi, the Amanitas, and certainly the luminous fungi he has seen did not appear to form any exception to the usual fate of fungi in general of being abundantly attacked by various species of insects.

In both of these cases, the photogenicity may be like the fluorescence of extracts of the common firefly, *Photinus pyralis,* and of cultures of *Bacillus fluorescens liquefaciens*—merely a property of some chemical substance elaborated by the life processes of the organism, and having no bearing upon its economy.

In simple marine forms like *Noctiluca miliaris,* the *Pyrocystæ, Pyrosoma,* etc., it is possible, though unlikely, that the luminosity has a warning significance and it is obviously not a sexual character. These creatures exist in swarms, or in the form of communities—compound, or rather composite animals—and it would appear very probable that in them the possession of the power to produce light finds its usefulness in the fact that by its means they are enabled to communicate in such ways as their low state of organization may require.

It is perhaps a digression, but a few words may not be amiss as to why the emission of light would be more useful to marine creatures than some other modes of communication in use among land forms. The sea-water is full of currents, ever changing and wavering; it varies in density slightly in different portions, owing to slight variation in concentration and in temperature. Therefore, the emission of a substance to produce olfactory or gustatory sensations would be of little use as a means of communication, especially to a creature capable of motion, as many luminous forms are; they would have far more control over their own movements than over that of any emission. The pro-

duction of a sound would be better so far as transmission is concerned, for water is an excellent transmitter of sound; but to produce a sound, especially under water, a not inconsiderable amount of power is required—as may easily be demonstrated by trying to clap one's hands under water—and this amount of power is far and away beyond any possessed by the luminous marine creatures. True, some fish emit sounds—*e. g.*, the drum-fish—but those marine creatures which do so are of considerable power and a quite high degree of organization. All living creatures, probably without exception, produce a certain amount of heat through their life-processes; but heat is obviously of no value so far as the purposes of communication are concerned, especially in an immense body of liquid of high specific heat. Variations in pressure more especially vibrations of longer interval than those of sound, may, of course, be produced and transmitted very effectively, but here again much power is required. As a matter of fact, some species of fishes have been found to possess along their lateral line, organs susceptible to vibration-frequencies approaching six per second in the water. Electricity is a possibility, but in all cases of electrical tissues so far studied, considerable masses of muscular tissue have been found as the site of the electrogenic phenomena, again a matter out of the question for a simple organism. With light the problem is different: All that is necessary is the elaboration by the cell through its vital processes of a substance which, when in contact with the oxygen dissolved in the sea-water, will produce light. Since certain bacteria can produce such a material from a compound as comparatively simple as asparagin (amino-succinamidic acid, $CONH_2 \cdot CHNH_2 \cdot CH_2 \cdot CO_2H$), this is a matter of comparative ease and requiring nothing more than the metabolic processes which might be ordinarily expected. After synthesis, the substance when brought into contact with the sea-water would be oxidized with the evolution of light. Light knows little of water currents, and but little more of differences in concentration; it would spread in all directions from the point of emission, and to the delicate structures of the ocean fauna and flora, would, however weak it might appear to human eyes, be sensible for considerable distances. Hence light is an ideal method of communication for marine forms of low organization and indeed for many of those of higher organization.

Returning again to a discussion of the various forms: Perhaps the first case, in the upward scale, where we may apply with any degree of certainty one of the uses mentioned before, is that of certain marine worms, the Annelids. Professor W. T. Galloway has recently shown the use of photogenicity in a species of Odontosyllid as a mating adaptation, with evidence which leaves little ground for doubt. In this case propagation of the species appears to be entirely dependent upon a periodic photogenicity limited to certain more or less definite por-

tions of the year, of the month, and of certain hours of the early evening, during which the male is attracted from below to the luminous female at the surface. Various species of earth worms have also been reported to be photogenic, and it seems probable that the usefulness of the luminosity in this case is somewhat the same as in the Odontosyllid mentioned above.

The bivalve *Pholas dactylus* presents another anomaly, however, for it lives a rather sedentary life, and is certainly not poisonous, at least to man. Yet it possesses definite photogenic organs. Although it is possible that in this case the luminosity is protective, we probably have here one of the cases of the limited use of photogenicity, not yet discovered.

Among the Crustacea there are several interesting cases of photogenicity, and in regard to them, and indeed to the whole subject of the use of "phosphorescence" in sea-forms, Alcock's interesting book "A Naturalist in Indian Seas," is well worth reading. Certain shrimp-like crustaceans throw out from glands, corresponding to kidneys, a substance which in contact with sea-water produces clouds of bluish light. There seems but little doubt that this is defensive in nature, and acts in much the same manner as the "ink" of the cuttle-fish. Some of these prawns are provided with enormous eyes, others with only rudimentary ones, and some with none at all. Alcock also mentions a large spider-crab, which, although completely blind, "shone like a star." Here we may readily conceive the light is alluring in function, serving to attract the creatures on which the crab feeds.

Among the insects we find the most widely known cases of photogenicity, and probably, also, the greatest field of usefulness. With the true fireflies, the Lampyridæ, the evidence that has been collected tends to show that the possession of the photogenic function is primarily a secondary sexual character. It has long been known that if the female of the European glowworm (*Lampyris noctiluca*) were exposed by night, a male would shortly come to it. The use of the photogenic function as a secondary sexual character has also been shown for the Italian luciola, and for certain of the fireflies common in the eastern United States (*e. g., Photinus pyralis*), and it appears probable that the same thing applies to the entire family. Curiously enough, the true "lightning bugs" show but little tendency to come to ordinary lights, though in *Photinus pyralis* either sex will respond to a small electric bulb operated in imitation of the light of the opposite sex.[1]

Among the Pyrophores, the Elaterid fireflies of the tropics, such as the cucuyo of Cuba, the luminosity very probably plays the same rôle as in the Lampyrids. These insects give a light which is continuous, though of varying intensity, instead of a flashing light as is emitted by

[1] McDermott, *Canad. Entomol.*, 1911 (in press).

the Lampyrids generally, and it is of interest to note that they may be attracted by an ordinary light.

To be sure, a great many insects which are not luminous themselves are attracted to light, and there is some evidence that this is something which the insects themselves can not help. The phenomenon of attraction to light among luminous insects, however, must be regarded as of particular interest, and as being most probably voluntary.

That the photogenic function in insects may also be protective or warning in significance may scarcely be doubted. The Lampyridæ, as a group, are soft, easily crushed insects, slow of motion, and often, in the females, apterous, or of but slow and labored flight. It has indeed been observed that the flash of these insects has a tendency to discourage pursuers, perhaps frightening them in some cases, but probably more often warning them that the light-bearer is inedible. The elaters are better protected by their hard, external chitin, than the soft-bodied Lampyrids, and hence it is unlikely that their luminosity has much protective purpose. So far as its possible use as a lure for prey is concerned, this is out of the question for the elaters, and also for many of the adult winged forms of the Lampyrids; the larvæ and probably some of the larviform females of Lampyrids, however, are carnivorous, and in them it is possible, though hardly probable, that the alluring significance for the photogenic function may hold good.

A few species of myriapods are known to be luminous; perhaps more species than are now known to possess this function actually possess it for short periods during the year, probably during the height of the mating season. In some myriapods, the luminosity seems to be developed in a secretion which is ejected from pre-anal glands, while in others it is located in organs on the body of the creature, as in the insects. Mrs. Thomas has shown the almost undoubted defensive character of the first class of luminosity in myriapods, while the observations of Bruner suggest rather the sexual significance in the second class.

Among the Cephalopods we find a very peculiar class of luminous organs, occurring immediately upon or just beside the eyeball, which in these creatures is often relatively enormous. Here the significance of the luminosity seems to be interpreted by the situation of the organs as an adjunct to the function of sight, and such it very probably is. But very similar organs are found on various other portions of the body and in situations where they can not very greatly aid in vision, or illuminate the creature's path through the water. Much the same thing is true of some fish, which possess one or more large photogenic organs situated near the eye, and rows of smaller organs along the sides or abdomen; here the organs near the eye are naturally considered as an aid to vision, while the others can not possibly be so considered. In

both fish and cuttlefish the explanation of these body-organs is probably the same. In the depths of the sea colors are practically indistinguishable. The dim light of the stationary photogenic forms there would be insufficient to differentiate colors. But in the more than semi-darkness of these depths, a creature with a row of luminous dots along its sides would show up like an electric sign in a dark street. The arrangement of the light-giving spots could very easily be followed, even for considerable distances through the water. It is probable, therefore, that these rows of photogenic organs on the bodies of these creatures serve the purpose of plumage and pigmentation on land, a welcome for friend and a warning for foe. No doubt one species of fish, seeing a luminous streak some distance away through the water, could readily tell whether its pattern of light—its "electric sign"—spelled the same as those upon its own body, or the legend of a foe. Many of the fish that possess these rows of luminous organs, while insignificant in size, are obviously raptatorial, and are armed with vicious teeth.

Of course another expression of the luminosity of deep-sea as well as surface fish is that it is alluring. This is especially true in those species which are provided with luminous barbels, or baits, like those of the angler-fishes. Alcock mentions a blind angler-fish with a luminous barbel, in which the alluring significance is scarcely to be doubted.

An objection which seems to have been urged against the "pattern" theory of photogenicity in marine forms is that different specimens of the same species occasionally show variations in the number and distribution of their lights. It seems probable, however, that the reason for this variation may be the age of the specimens of the fish in question, the number or position of the spots varying with age. Almost any of the various books and papers on the deep-sea fish will illustrate the effect of this "pattern" arrangement as seen, for example, in *Cyclothone* and *Astronesthes*.

Still another type of organ of light-production among fishes is illustrated in Carl Chun's book "Aus den Tiefen des Weltmeeres"; in this case the luminous apparatus is set in a pit in the foremost part of the head, before the eyes. Here there can be little doubt, again, that the usefulness to the animal consists in the illumination of the "road ahead," as the searchlight does for the automobile.

A large number of other forms might be mentioned, which emit light in more or less characteristic ways, but what has gone before will serve to illustrate the majority of the points in interest. Some considerations as to the phenomenon in the fireflies may, however, be of interest, especially as deductions therefrom will doubtless hold true for many other luminous forms also.

It has been observed that the various species of fireflies (Lampyrids) emit lights of slightly differing tone, and in decidedly different man-

ners. For instance, the observer would soon notice that the lights of *Photinus pyralis* and *Photinus scintillans* were decidedly more yellowish than those of *Photuris pennsylvanica* and *Lecontea lucifera*, and that the latter were distinctly greenish in tone. A little further observation would soon enable one to distinguish these two latter insects from the two former ones also through the different method of light-emission; the flickering flashes usually given by *Photuris* and *Lecontea* differing markedly from the long flash of the *Photini*. Thus it becomes probable that different species can recognize their own kind through the color and manner of emission of the light.

Another interesting circumstance is that the majority of Lampyrids have their luminous apparatus on the ventral side, the greater part of the light being directed downwards and sideways, and but very little passing upward. The effect of this ventral arrangement so far as the sexes is concerned is that a female resting on a leaf or on the ground illuminates by her flash a considerable portion of the supporting surface, and a male flying above her would see not merely a flash, but a silhouette of his mate against an illuminated background. The green color of the light would, of course, be of special advantage on foliage. Moreover, the flash of the flying male would illuminate most particularly an area immediately below him and ahead of him, as these insects fly with the body inclined, the head being highest. In species where the male is non-luminous, or but slightly so, this last service does not exist, while in those like *Photuris*, where both sexes are about equally active, the manner of applying the luminous property may be entirely different; it is perhaps significant in this latter group, that the light is easily visible from the dorsal side between the elytra. The cucuyo (*Pyrophorus noctilucus*) in which both sexes are equally active, have lights both above and below.

We have been considering the purpose of biophotogenicity so far as its application to the creatures possessing the function is concerned, and to a more limited extent, to their enemies. A few words may well be given regarding its relation to man. The use of the cucuyos as decorations and as night-lamps in the tropical countries is quite well known, and a number of instances have been recorded where travelers have owed their safe passage and even their lives to the light given by a collection of these Elaterid beetles. Several naturalists have written and read by the light of vessels filled with *Noctiluca* and other sea-organisms, and Chun has photographed a Cephalopod by means of its own light. The luminous bacteria have been put to a number of uses, mainly in the laboratory; flasks coated on the interior with fresh cultures of some of these organisms give light which appears of considerable intensity when the eye becomes accustomed to it, and Dubois and Molisch have taken quite a number of photographs by bacterial light. It has

been suggested that "living lamps" made from these bacteria could be used to advantage in coal mines and powder magazines, since as they emit no appreciable heat, they would be absolutely without danger of producing an explosion. They would certainly furnish a nice cool light for use in summer; the author would very much like to have one here in his little study now, in place of the Welsbach which is engaged in turning some 98 per cent. of its expended energy into heat instead of light, after a day that has shown 90° F. However, such lamps would probably not do for anything like general illumination, even if the intensity were great enough, for in their light any color effects beyond a very limited range would be impossible. Color considerations would not be a considerable factor in mines and mills, however, so this does not interfere with this application.

It is more reasonable, however, to consider that these luminous forms merely point to what is possible in the way of efficient light—to serve as the goal to which all effort in the improvement of light-efficiency must strive. This must be the ideal—light without heat.

THE WATER RELATIONS OF DESERT PLANTS

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WHILE working as a student in the laboratory of Professor O. P. Jenkins at DePauw University twenty-three years ago, a typewritten schedule of experiments in plant physiology by Professor J. C. Arthur was placed in my hands as a guide in some practical work that was to extend throughout the collegiate year. The program in question probably constituted the first attempt of its kind in an American school, and its series of demonstrations may be taken to represent with fair accuracy the concepts and assumptions which might be safely presented to a student at that time.

Sachs and his students had made contributions of immense importance in growth, organogeny, irritability and tropisms in general, but the first serious efforts at analysis of the physical phenomena underlying the action of organisms may be assigned to Pfeffer and DeVries. Pfeffer established the principles of osmosis by a study of the behavior of crystalloidal substances toward membranes, the results of which were published in 1877, and in the same year DeVries brought out his contributions on turgidity. To the latter we owe the first systematic analysis of turgor, and of the mechanism by which the rigidity and firmness of soft-bodied organisms are maintained and by which movements are executed. The plasmolytic method for the detection of the differential action of substances and membranes, and the establishment of the principle of isotonic coefficients were also the work of DeVries. Both of these authors were intent on finding the solution of problems in plant physiology, in which they were notably successful, but their results form the basis of the dissociation theory of Arrhenius, and theory of pressure in solutions of van't Hoff, which together may be regarded as the basis of modern physics and chemistry.

It seems highly characteristic of research in plant physiology that devotion to many of its problems may lead the student far afield from botany, or the stricter domain of biology. The worker in this subject frequently finds it necessary to build cantilever bridges across chasms which yawn in front of him to find that the farther ends of his spans comes down to the solid ground of chemistry, physics, climatology or geology. At present, however, he has come upon rifts which he can not cross without aid from the farther side.

The conclusions of DeVries and Pfeffer, impressive as to their inclusiveness and with some of their applications ranging far ahead of the science of the time-yielded methods of practical calibration of a large number of biological processes and set physiology in the way of becoming an exact science. The water-relations of the organism have always stood out as a subject of great importance, and as the main aspects are presented with less complication in plants, where the essential features are not complicated by a circulatory system, it has naturally followed that the principal contributions have been made by workers who attacked the problems involved from a botanical point of view.

Osmotic action, being earliest and best known, has had thrown upon it the entire burden of the explanation of the water-relations, and all of the mechanical action of the organism which might in any manner be attributed to pressures originating by the action of electrolytes. One contemplates departures from it, as set out in text-books, with regret; but some very substantial modifications of our conceptions with regard to these matters are long overdue.

The simpler phenomena of swelling and of changes of form due to the imbibition action of wood, starch and other material in a colloidal condition found place even in my preliminary directions for work: it was well recognized, however, that secretion, excretion and the accumulation of water anywhere in an organism were not fully comprehensible on the theory of osmotic action, and I can still recall that while trying out the simple tests in plant physiology which had been outlined for me, and which were calculated to give an encouraging sense of sufficiency to the student, the professor of biology was leading us into a consideration of the action of the epithelial cells and of other tissues which presented many features not explainable by osmosis. However much this inadequacy may have impressed my teacher, candor compels me to say that it did not bear too poignantly upon me, and I was willing to leave these as well as many other troublesome things to such all-embracing causes as "special physiological action" or any other convenient bogie, as being entirely too mysterious for a beginner.

Osmosis has indeed brought us far, and the briefest review will demonstrate the tremendous strides that have been made by its application. Our conceptions of turgidity and of processes which depend directly upon cell-pressures are so well-established as to be subject to but slight possible modification. It is not so, however, with many other phases of the physiology of the cell. The greater mass of an organism is colloidal, complex as to constitution, diverse as to reaction to acids, alkalies and electrolytes in general, and lastly having highly specific inter-actions among its constituents. It is bodies or masses of this kind that are to be dealt with when considering the action and morphology of the chromosome, chlorophyll bodies and cell-organs in general,

as well as the nature and action of the membranes of the living organism The opinion is hazarded that further advances in cell-mechanics will await some more definite physical knowledge of the colloidal bodies whose evolutions and involutions are the center of the morphological interest in cytology. A systematization of the water-relations of these bodies, and of the changed qualities resulting from contact and action of other cell-constituents is demanded: determination of chemical structure is of ultimate importance, but not so immediately necessary to the physiologist, who would now welcome a return from the chemist and physicist of the service rendered them earlier by botanists.

The water-relations, now as earlier, hold the center of the stage in physiology, especially in plants. In a final analysis it might be truly said that it is to the immanence of this subject that the establishment of the Desert Laboratory is due. It may be profitable to discuss some of the problems which present themselves to those of us whose activities center at that institution, and to take a glance at the living material which has developed under water-conditions quite unlike those of this and other regions with a moist climate. I am confident that I speak with the concurrence of my colleagues when I say that whatever results of importance we may have accomplished must be attributed largely to the living plants available for our work and the environmental conditions which furnish a background for our experimentation.

If organic response to environic factors is to be taken as a potent means to evolution some striking features might be expected in the southwestern deserts; and when one looks up and down the slopes of Tumamoc hill, or across the washes to the bajadas of the Tucson mountains, types of vegetation not seen in regions with more moisture are seen everywhere. Furthermore, it needs only a brief acquaintance with the desert to know that the animals which find food and shelter in this vegetation show structures and habits equally pronounced.

Two general types of plants may be seen away from the streamways: one comprises species of annuals and perennials with retarded stems, branches reduced to spines, small, narrow, hardened and waterproofed leaves, which send their roots to only a moderate depth in the soil occupying a kettle-shaped mass, being of the generalized type of Cannon. It may be explained at this point that the moisture of desert soils available to plants is in the more superficial layers which are wetted by the rains. The spinose plants now under discussion contain a very small proportion of water: their bodies are hard, with a minimum of development of cortex or pith, and they hold only a small amount of sap in the protoplasts or suspension colloids of the cells. This juice, however, is characterized by the fact that it generally contains a very large proportion of salts or compounds which exert osmotic pressure. The state of the cells may be determined by the use of plasmolytic meth-

ods in which the strength of a solution, such as cane sugar or potassium nitrate, which will balance the solution in the cell is measured, or by extracting a certain measured amount of living material which has been crushed with distilled water and after the freezing point of this extract has been found the original pressure may be calculated. The simpler process of squeezing out sap and testing its freezing point can not be used in a large number of instances since the highest pressures that can be applied fail to bring out the scanty sap from some species. The use of such methods at the Desert Laboratory demonstrates that the leaves of the creosote bush (*Covillea*, or *Larrea*) (Fig. 1) may have

FIG. 1. *Covillea* (*Larrea*), THE CREOSOTE BUSH, THE MOST WIDELY DISTRIBUTED SHRUB WITH RESTRICTED SURFACES IN AMERICAN DESERTS. The leaves show osmotic pressures equivalent to over 75 atmospheres.

osmotic pressures of 75 atmospheres, the upper parts of the stems 35 to 60 atmospheres, and the basal portions of the stems 35 to 50 atmospheres. Fitting, by the use of plasmolytic methods on plants in the Algerian deserts at Biskra, found pressures in leaves of plants of this type of over a hundred atmospheres. These pressures would support a column of water 250 to 300 feet high.

It is notable that plants of this type are constantly in absorbent contact with the soil, and apparently continue to derive some water from it even in the driest times, as evinced by the fact that they wilt quickly when taken up. Such forms are very difficult to transplant. A misapprehension as to the influence of concentration of sap upon transpira-

tion has long been current, and I must plead guilty to some participation in statements tending to perpetuate the mistake. It may be easily found, however, that even the maximum pressures noted above would not retard transpiration as much as ten per cent. from that which would take place with a sap of distilled water. One of my reviewers has recently made a variation of this mistake in suggesting that acidity would have a retarding effect on water loss. No foundation exists for such a supposition.

Almost any ordinary branching plant with broad leaves will, if forced to carry out its development under arid conditions, show some of the features of the type of desert plants described, and it is customary to assume that the causal conditions responsible for such forms are the desert factors: that we have here a direct adaptation or environic response which has become heritable in the strictest and fullest sense. This is a matter that deserves the fullest consideration. Meanwhile it will be perfectly safe to assume that such spinose forms represent the simplest or most elementary specializations of desert plants, and species with the most diverse morphological constitution may show alterations of this character. The sclerophylls of the American desert include species of *Prosopis, Acacia, Calliandra, Parkinsonia, Cercidium, Olneya* of the leguminous plants, *Covillea* and *Zizyphus* of the Zygophyllaceæ, *Fouqueria, Lycium, Koehberlinia, Condalia, Manzanita, Franseria, Jatropha, Sapindus, Vauquelinia, Quercus, Aster* and others.

Southwestern America has been arid for an extremely long period, not uniformly so, however. The researches of Professor Ellsworth Huntington, in which evidence has been obtained from ruins of structures built by man, of geological terraces, lake beds, strands and drainage lines in Central Asia, Palestine, and America, and also by the examination of the structure of the big trees of California, seem to justify the conclusion that variations in climate with regard to temperature and moisture have taken place within the last two thousand years that would be of profound biological importance. It seems fair to assume that similar oscillations, each movement of which might extend over a few hundred years, have taken place previously.

It is under these conditions therefore that we are to think of the evolution of the desert vegetation of the southwest, and present knowledge compels us to believe that much of it originated somewhere within the limits of the region which is arid at the present time. Perhaps the most important constitutents of this indigenous specialized flora are the cacti, which must have originated somewhere in the Mexican highlands in the Tertiary or later. This group is known to contain over a thousand species, and now extends through South America, its distribution offering some most highly localized occurrences of species. So rapid has been its evolution, and so wide the amplitude of its depart-

ures from the prototypes, that the relationship of the group is very difficult to determine.

Chief interest in the present connection lies in the fact that in the evolutionary movement the members of the group have undergone all of the specializations of the spinose forms in addition to a number of others of even more sweeping morphological importance. Stems have been reduced and branching restricted: leaves are retained by some; in others, such as the prickly pears, they appear only as rudiments dropping off before maturity, while in others, such as the great melon cacti and the sahuaro, they are not visibly represented at all. So far does the general reduction go in the *Echinocacti* or melon cacti that the adult plant consists of a short stem, a few inches, or at most less than two yards high, unbranched, and bearing only two types of spines which may be taken to represent the rudiments of atrophied organs, or specialized organs, largely according to the morphological prejudices of the observer. These plants represent the climax of specialization to desert conditions and the end result of the influence of aridity on the development of land vegetation.

In these succulents which constitute the highest group of desert plants, the cortex and medulla of the stems are exaggerated to an enormous extent and the greater bulk of the plant consists of a parenchymatous tissue with mucilaginous cell-contents, which gives to the

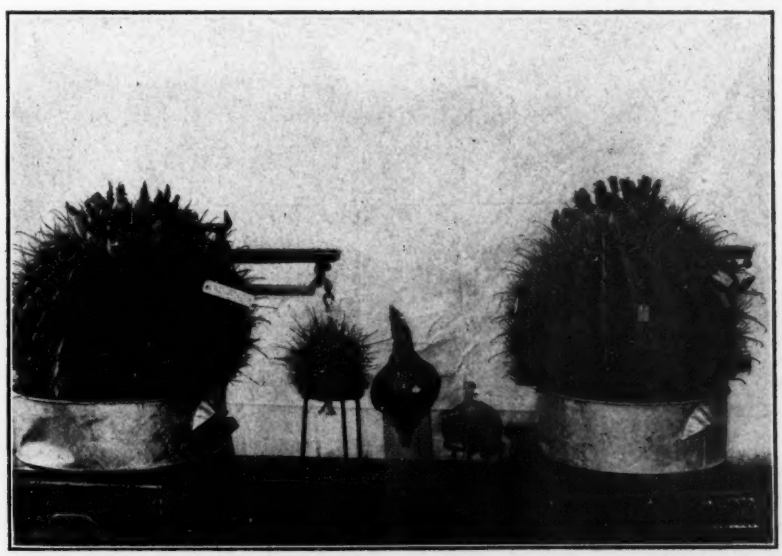

FIG. 2. A GROUP OF *Echinocacti* AND *Ibervillea*, ISOLATED FOR DETERMINATION OF THE RATE OF WATER LOSS. Succulents of this type have osmotic pressures of less than 12 atmospheres and absorb water only from soils containing large proportions of moisture. Some of these individuals have been without an external supply for thirty-eight months.

plant the physical qualities of a huge roll of jelly. The comparison may be made more inclusive, however. As the spinose plants have a sap high in electrolytes, mineral salts, or of substances showing osmotic activity, so these plants are rich in suspension colloids, and simulate a mass of gelatine capable of taking in and holding great quantities of water. The most sketchy knowledge of the colloids prepares one to learn that the sap of these plants shows a very low osmotic pressure under ordinary conditions of growth. The melon cacti of Arizona have a drinkable sap which shows but 3 to 5 atmospheres of pressure, the

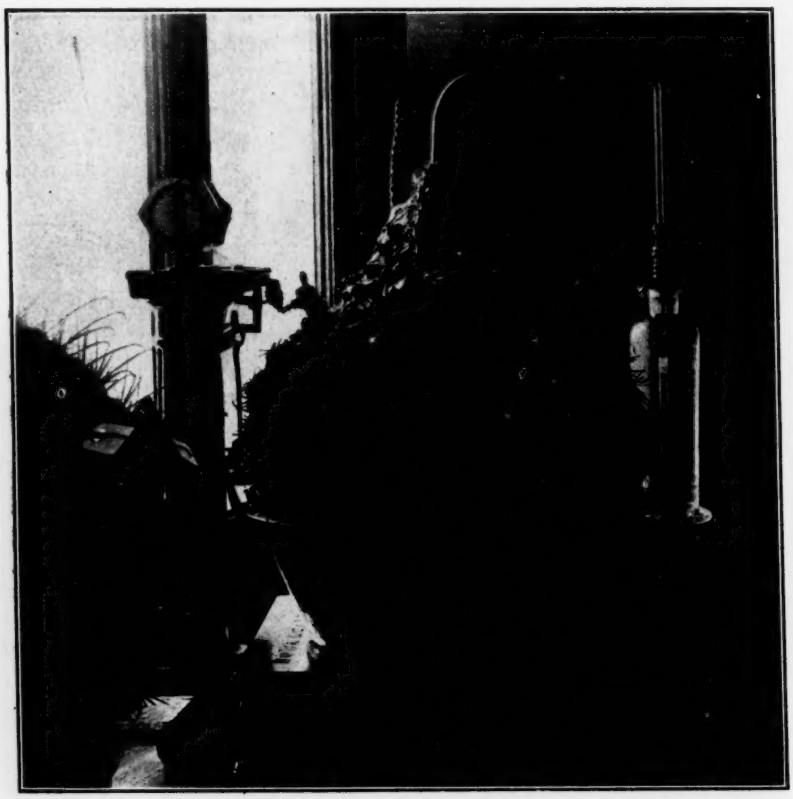

FIG. 3. AN INVERTED *Echinocactus* ABSORBING WATER THROUGH A CLAY CUP IMBEDDED IN THE BASAL PORTION.

great tree cactus with its mucilaginous juice varies from 7 to 10 atmospheres and the opuntias (cylindrical) as high as 10 to 12 atmospheres (Fig. 2.) These values are to be contrasted with those given above for the spinose forms, which are seven to thirty times as great and with such ordinary broad-leaved shrubs as the lilac, in which pressures from 20 to 30 atmospheres are the rule.

These purely physical features of the succulents are correlated with habits and modes of activity widely different from those of the spinose

forms. The latter penetrate the soil more deeply and are in constant absorbent contact with the soil. The succulents of southwestern deserts, without exception, have a wide-spreading root-system horizontally disposed immediately under the surface of the soil in a layer which is wetted by even a slight precipitation. An increase in moisture is the stimulus which starts the development of myriads of small absorbent rootlets and these have an absorbent capacity which results in the passage of a very large amount of water into the body of the jelly-like plant within a very brief period. (Fig. 3.)

As the rains come to an end the soil moisture soon dries to a limit in which the absorbent elements of the cacti may not act, these die and the plant stands or sits inert, anchored by the heavier roots in a soil with which it bears almost no important physiological relations until the coming of the next rainy season. It was to determine some of the features of the behavior of these plants during periods of extended deprivation of water that my own observations on the water-balance were begun in 1908 and are still being continued.

It is pertinent to say at this point that the halophytes, fleshy plants of seashores and saline areas, are not succulents in the present meaning of the term. These forms contain a large proportion of water, but it is held at high pressures (*Cakile* as high as 50 atmospheres, according to Lloyd), their transpiration rate corresponds with the proportion of water which they contain and water loss is consequently rapid, and as a further consequence they wilt quickly. An interesting capacity to vary the pressure of the sap in the absorbing organs has been found by English botanists.

The transpiration or loss of water from leaves or green organs of a plant may be roughly compared to the drying out and shrinkage of drops of wet gelatine; but with the modification that comes from the enclosure of the gelatine in small capsules arranged inside a chamber whose bounding walls are fairly water-proof, but which have ventilating openings, hundreds of them to the square millimeter. It would be as if a room were piled full of parchment bags distended with thin mucilage; the walls of the bags would undoubtedly be wet and water vapor would be constantly given off into the air-spaces at a rate very little affected by the composition of the water with which the mucilage is moistened. Furthermore, if the windows were open, the water vapor would be carried out and the total amount remaining lessened constantly.

The accentuated conditions at the Desert Laboratory have been favorable for the observation of a phase of transpiration which has been noted there for the first time. The transpiration of a leaf increases with the rising sun in the morning and the rate is accelerated until sometime in the forenoon, when, with all of the atmospheric factors at

an intensity that would facilitate water loss, the rate suddenly drops, with the stomata still open. The theoretical explanation offered for this break by Professor Livingston would assume that the outer walls of the jelly-like cells are coated with a film of water from which evaporation takes place and which is constantly supplied from the cell. When the evaporating power of the air causes a loss in excess of the rate at which the film may be renewed from the cell, the film breaks, and evaporation now may take place from the interstices of the walls only. If the wall of the cell were supposed to be of brick laid in mortar and coated with plaster, the plaster would correspond to the film and the mortar between the bricks to the water from which evaporation could take place after this "incipient drying," as it has been termed, has taken place.

Excessive water loss may proceed with or without the breaking of the film to a point where the turgidity or pressure of the cells is lessened, with the result that the leaf wilts. The wilting point is not a constant, but is mainly the product of the retentivity of the soil and of the evaporating power of the air, both of which may vary widely. The evaporating action of the air may be calibrated exactly at any time, and it is proposed by Professor Livingston that the standard of wilting point for a test species might be one of the most valuable expressions of the agricultural value of a soil.

The action of stomata inevitably comes up in any consideration of transpiration: the beautifully regular structure of these organs, and their delicate action, have led to some extremely fanciful interpretations of their self-regulatory mechanism. Time suffices only to say that the condition of the stomatal openings concerns not only transpiration but also photosynthesis and respiration, and any scheme of automatism for action in response to any one of these processes would at times be highly detrimental to the other functions. Of recent contributions to the physiology of these organs, Lloyd's consideration of the manner in which carbohydrates are drawn into the guard cells and are concerned in the making or loss of turgidity, and also his method of determination of the actual state of the stomata on a leaf at any moment by instantaneous fixation of a strip of detached epidermis must be reckoned to be of great importance. Frances Darwin has recently devised a porometer which measures the rate at which air may be pulled through a leaf from one surface to the other, thus obtaining a basis for the calculation of the average condition of the stomatal openings. Such refinement of methods and perfection of apparatus will permit a much more accurate calibration of leaf action than has been possible hitherto.

The enormous accumulations of water in the bodies of cacti and other succulents raise questions as to the part such liquid may play in the life of the plant and some observations to test the matter were begun

in 1908. An afternoon in October, 1909, was spent in felling and cutting up a tree cactus (*Carnegiea* or *Cerus giganteus*), near the Desert Laboratory, which consisted of a single cylindrical trunk 18 feet in height. The total weight was nearly a ton, and a section was found to contain over 91 per cent. of water, showing that the entire plant held over seventeen hundred pounds of water, or about five barrels.

It has previously been pointed out that during the dry season these plants sustain only an anchorage relation with the soil, and that absorption ceases wholly. The experiments were therefore planned to detach a number of individuals of the sahuaro (*Carnegiea*), the melon cactus (*Echinocactus*), and various opuntias from the soil, place them on suitable supports in the accustomed upright position and thus simply lengthen the dry seasons to which they had been subject. Accidents in nature tear many individuals loose from the soil and they may not be able to perfect a new root-system for many months, so that the observations closely simulated happenings in the history of the species involved. Some of the test plants were placed in the open air, some in the more equable conditions of a well lighted laboratory room, a few were kept for periods of a few months in constant temperature dark room, and others were exposed to the full blaze of the Arizona sunlight, standing on a base of black volcanic rock, thereby avoiding none of the desiccating effects of the climate.

The formidable armature of the bulky bodies of these plants made their manipulation a matter of some difficulty and discomfort even with the best supports and harness that could be devised. The larger ones were placed on platform scales, where they were allowed to remain undisturbed. The majority, however, were mounted and two or three men were necessary to handle them in the weighings which were made at intervals correlated with the season and the rate of loss.

All individuals showed a high rate of loss when first taken from the soil, the excess being attributed to the evaporation from abraded surfaces of the roots and stems. Next it was found, of course, that the rate of loss was least during the cooler season, at which time an *Echinocactus* might lose as little as one forty-thousandth of its weight in a day, and on the other hand during many days in the hot dry season the daily loss was one three-hundredth of its total weight. The minimum of the tree cactus was one nine-thousandth of its total and the maximum was about that of the *Echinocactus,* although not measured under equivalent conditions.

Chief interest in the rate of loss, however, centers about the behavior of these plants from season to season, especially when the amount of water on hand was taken into account. In work of this kind it is found convenient to use a standard of succulency which calculates the number of c.c. of water to 100 sq. cm. of surface. Thus a great melon cactus

weighing nearly a hundred pounds had a succulence of 3 on the scale noted, in which condition it transpired water at the rate of 10 g. daily. A year later the succulence had fallen but slightly, being 2.8; the rate of transpiration, however, had decreased to one half, being now but 5 g. daily.

The theoretical explanation of the sudden drop in daily transpiration given above will not suffice for this case which is a comparison of successive seasons. The slowness of the rate of loss would allow ample time for the diffusion from the great water-balance of the plant to take up a deficiency at any given surface. Morphological alterations are not found, and the theoretical explanation that presents itself would be that the colloidal condition of the walls, or inner membranes had been altered. The altered concentration of the cell-sap with its included acids and other substances might well be responsible for a change similar to that which takes place on the surface of a plate of jelly when acted upon by various reagents. A second phase of interest in the acids of the sap was found in their daily variations. Earlier the determinations of the acidity of the sap were made rather at random, with the general result that it was seen to be not affected by progressive desiccation. Within the last few months, however, Professor H. M. Richards has gone into this matter more exactly, with the astonishing discovery that the acidity of these plants is very great in the morning and decreases steadily throughout the day until evening, when it begins to rise and continues to increase until morning. So great is the amplitude of this change that a cactus may contain four times as much acid in the morning as at sunset. It is needless to say that the problem as to the making and fate of this acid is a matter that excites the keenest interest in connection with the respiration and food-construction processes in the plant. At present the change seems to be directly dependent on the course of the temperature. It is to be recalled that the water-holding power of the cell colloids must be notably affected by this variation in the acids of the cell.

The probability of the absorption of water vapor from the air by plants of the desert is one of perennial interest, especially to those who take a sentimental view of desert life. The spines of cacti, especially the large curved and hooked ones of the *Echinocacti*, will take up water vapor, as has been demonstrated more than once in my work, but the very small amount of moisture thus acquired is not available to the living cells and is quickly lost when the plants are exposed to direct sunlight. The bark of the ocotillo (*Fouquiera*) will absorb liquid water and yield it to growing tissues, as has been found by Lloyd, the hairs of some south African succulents have been found to absorb moisture, and the fleshy beach plants will absorb either water vapor or liquid water through the leaves, especially when in a desiccated condition. Doubtless

the heavy fogs of the California coast are in this way a source of supply for *Cakile* and other halophytes. In none of these cases, however, is the existence of the plants concerned so dependent upon atmospheric absorp-

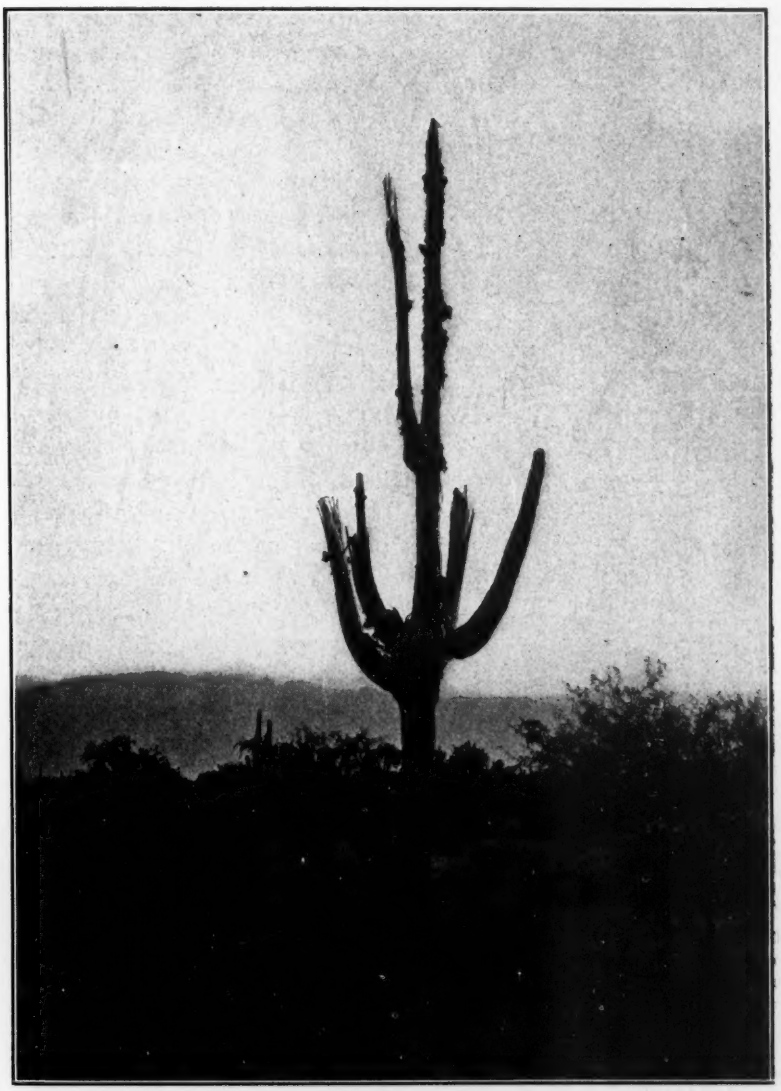

FIG. 4. A SAHUARO (*Carnegiea gigantea*) OF WHICH THE MAIN STEM HAS BEEN DEAD FOR OVER A YEAR, with three living branches, one of which bore flowers.

tion as has been found by Professor Peirce for the lichens which thrive in the fog channels leading up the valleys and over the passes along the Pacific shore.

Any study of this subject leads in the end to a consideration of the

value of the great water-balances described in the life of the plant, and one naturally asks the question as to how long an individual might survive at the expense of its great accumulated supply, and what activity it may carry on while cut off from the customary supply of soil moisture. The replies to these queries vary widely with the species considered. The tree cactus may live a year or as long as two years in the open in Arizona upon its balance. Growth and reproduction are in the main inhibited, however, by any notable depletion. Sometimes, however, the death of the main trunk of a plant leaves a living branch held high in the air, and this may bloom, but this action must be due to the special stimulation of approaching death. (Fig. 4.) The melon cactus may survive one or two seasons in the open, although when given some shade individuals have been seen to live three years, carrying on some apical growth and flower formation with the usual rhythm. The prickly pears survive, grow and carry on reproduction for even longer periods.

FIG. 5. AN INDIVIDUAL OF *Ibervillea sonoræ* WHICH HAS PRODUCED VINES AND FLOWERS WHILE ISOLATED. This may be repeated many seasons.

So far as physiological usefulness is concerned, stores of water accumulated in tubers, bulbs or thickened underground organs are far more effective than thickened aerial stems or leaves in holding a water-balance available to the plant for extended periods. *Ibervillea*, the "guarequi" of Sonora, has a thickened stem homologous with the "Big Root" of California, which is a relative, and it has been cited many times to illustrate observations of an individual which is still alive although detached from a supply since 1902, and has not received any notable addition since 1901. (Fig. 5.) The corms of *Brodiæa* form new small corms during desiccation, which are plump with the diminished supply on hand, and this process continues until the balance reaches the vanishing point in three or four years. The observations of Professor Campbell show that plants with so little external appearance of water-storage as the liver-

worts may hold a balance in mucilage cells, a capacity shared by an extremely large number of species.

A review of the extensive data accumulated establishes the fact that *Echinocactus* may live for nearly three years at the expense of its water-balance, which may be depleted as much as 50 per cent. before death results. *Carnegiea* loses nearly 30 per cent. before serious results follow, although the extremely succulent seedlings of this plant may shrink to one third the original weight and still live.

Plants with a large water-balance are especially characteristic of the arid regions of southwestern United States, Mexico, some parts of South America and South Africa. It is notable that the great deserts of central Asia and Asia Minor, as well as the whole of north Africa, have but few native species of this habit. Some succulent *Euphorbias* are reported from India, but information concerning the occurrence of plants with a large accumulation of water in Australia is very meager. The physical causes which might be operative in inducing this habit in representatives of widely separated families are not known.

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BUFFON AND THE PROBLEM OF SPECIES

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II

WE have thus far noted three generally disregarded but fundamental facts concerning Buffon's opinions about the nature of species. The first fact is that in his preliminary discourse in the first volume of the "Histoire Naturelle," in which he sought to apply the Leibnitian principle of continuity to natural history, Buffon's emphasis upon the continuity of the gradations between species probably had no evolutionary implications. The second fact is that the principal doctrine of this discourse is to the effect that only individuals exist in nature, while species exist only by grace of the human imagination, which, aided by human ignorance, sees sharp lines of cleavage among organisms where no such lines are. The third fact is that this doctrine was already tacitly but decisively abandoned in Buffon's second volume, where he represents species as real and well-marked natural entities, their limits being determined by the test of the sterility of the products of cross-breeding. There are, indeed, many later passages where the old phraseology incongruously recurs; but it recurs in contexts in which the reality of species is expressly insisted upon.

2. When the fourth volume of the "Histoire Naturelle"—the first dealing specifically with the lower animals—appeared in 1753, four years after the first three, Buffon's departure from the notions set forth in the preliminary discourse became still more evident. He had by this time, in the first place, been greatly impressed by the homologies in the structure of the vertebrates; he had come to see some significance in those facts of comparative anatomy which his own treatise—though more through the contributions of Daubenton than through his own—was for the first time setting in a clear light. The existence throughout at least all the immensely diverse vertebrate forms of an underlying unity of type, Buffon was, I suppose, the first to bring forcibly to the attention of naturalists and philosophers, as a fact calling for serious consideration and explanation.

> If we choose the body of some animal or even that of man himself to serve as a model with which to compare the bodies of other organized beings, we shall find that . . . there exists a certain primitive and general design, which we can trace for a long way. . . . Even in the parts which contribute most to give variety to the external form of animals, there is a prodigious degree of resemblance, which irresistibly brings to our mind the idea of an original pattern after which all animals seem to have been conceived. What, for example, can at first seem more unlike man than the horse? Yet when we compare man and horse point by

point and detail by detail, is not our wonder aroused rather by the resemblances than by the differences to be found between them? . . . It is but in the number of those bones which may be regarded as accessory, and in the lengthening or shortening or mode of attachment of the others, that the skeleton of the horse differs from that of the human body. . . . The foot of the horse (as M. Daubenton has shown), in appearance so different from the hand of man, is nevertheless composed of the same bones, and we have at the extremities of our fingers the same small hoof-shaped bone which terminates the foot of that animal. Judge, then, whether this hidden resemblance is not more marvelous than any outward differences, whether this constancy to a single plan of structure—which we can follow from man to the quadrupeds, from the quadrupeds to the cetacea, from the cetacea to birds, from birds to fishes, from fishes to reptiles—whether this does not seem to show that the Creator in making all these used but a single main idea, though varying it in every conceivable manner—so that man might admire equally the magnificence of the execution and the simplicity of the design.

But consideration of the anatomical homologies did not lead Buffon merely to pious reflections. He saw clearly and unequivocally declared that this unity of type forcibly suggests the hypothesis of community of descent. To one who considers only this class of facts, he wrote:

Not only the ass and the horse, but also man, the apes, the quadrupeds, and all the animals, might be regarded as constituting but a single family. . . . If it were admitted that the ass is of the family of the horse, and differs from the horse only because it has varied from the original form, one could equally well say that the ape is of the family of man, that he is a degenerate (*dégénéré*) man, that man and ape have a common origin; that, in fact, all the families, among plants as well as animals, have come from a single stock; and that all animals are descended from a single animal, from which have sprung in the course of time, as a result of progress or of degeneration, all the other races of animals. For if it were once shown that we are justified in establishing these families; if it were granted that among animals and plants there has been (I do not say several species) but even a single one, which has been produced in the course of direct descent from another species; if, for example, it were true that the ass is but a degeneration from the horse—then there would no longer be any limit to the power of nature, and we should not be wrong in supposing that, with sufficient time, she has been able from a single being to derive all the other organized beings.

Buffon thus presented the hypothesis of evolution with entire definiteness, and indicated the homological evidence in its favor. But did he himself regard that evidence as conclusive, and therefore accept the hypothesis? The passage cited is immediately followed by a repudiation, ostensibly on theological grounds, of the ideas which he has been so temptingly presenting.

But no! It is certain from revelation that all animals have participated equally in the grace of direct creation, and that the first pair of every species issued full formed from the hands of the Creator.[20]

This repudiation has been regarded as ironical, or as inserted merely *pro forma,* by those interpreters of Buffon who have made him out a thorough-going evolutionist. Unfortunately, nearly all these

[20] "Hist. Nat.," IV., 1753, p. 383.

writers—dealing somewhat less than fairly with their readers—have failed to mention that his rejection of the evolutionary hypothesis was not put forth by him as resting *exclusively* upon these religious considerations. If the words just quoted stood alone, it would, indeed, be scarcely possible to take them seriously. But they do not stand alone; they are directly followed by arguments of quite another order against the possibility of the descent of one *real* species from another; and the essence of the most emphasized of these arguments lies in the Buffonian conception of the nature of species, already expounded in the second volume. In other words, the fact of the sterility of hybrids, and certain other purely factual considerations, were urged by Buffon as conclusive objections against the theory of descent.

Specifically, his arguments against evolution are three: (1) Within recorded history no new true species (in his own sense of the term) have been known to appear. (2) There is one entirely definite and constant line of demarcation between species: it is that indicated by the infertility of hybrids.

> This is the most fixed point that we possess in natural history. No other resemblances or differences among living beings are so constant or so real or so certain. These, therefore, will constitute the only lines of division to be found in this work.

But why, it may be asked, should the sterility of hybrids be a proof of the wholly separate descent of the two species engendering such hybrids? This question Buffon does not neglect to answer. An "immense and perhaps an infinite number of combinations" would need to be assumed before one could conceive that "two animals, male and female, had not only so far departed from their original type as to belong no longer to the same species—that is to say, to be no longer able to reproduce by mating with those animals which they formerly resembled—but had also both diverged to exactly the same degree, and to just that degree necessary to make it possible for them to produce only by mating with one another." The logic of this is to me, I confess, a trifle obscure; but it is evident that Buffon conceived that the evolution from a given species of a new species infertile with the first could come about only through a highly improbable conjunction of circumstances. (3) Buffon's third reason for maintaining the fixity of species is the argument from the "missing links."

> If one species had been produced by another, if, for example, the ass species came from the horse, the result could have been brought about only slowly and by gradations. There would therefore be between the horse and the ass a large number of intermediate animals. Why, then, do we not to-day see the representatives, the descendants, of these intermediate species? Why is it that only the two extremes remain?

Taking these three arguments into account, then, Buffon arrives at this conclusion:

> Though it can not be demonstrated that the production of a species by

degeneration from another species is an impossibility for nature, the number of probabilities against it is so enormous that even on philosophical grounds one can scarcely have any doubt upon the point.[21]

However plausibly Buffon's incidental expressions of deference to the testimony of revelation may be regarded as perfunctory and insincere, it would be absurd to suppose that he was also ironical in these legitimate and ostensibly scientific (however poor) arguments for the fixity of species—arguments which are closely connected with that conception of the nature of species which was perhaps his most influential personal contribution to the biological ideas of his time. We must conclude, then, that, while he clearly envisaged the hypothesis of evolution as early as 1753, and recognized that there was some probable evidence in its favor, he then seriously believed that the preponderance of probability was enormously against it. It is certain that contemporary readers must have understood this to be his position.

The same doctrine—that true species, as determined by the sterility of hybrids, are real natural entities and constant units amid the otherwise infinitely variable phenomena of organic nature—is repeated and emphasized many times in subsequent volumes of the "Histoire Naturelle." Thus in volume five (1755) Buffon—trying to retain as much of the principle of continuity as could be made consistent with his present view—writes as follows:

Although *animal species are all separated from one another by an interval which nature can not overstep,* some of them seem to approximate one another by so great a number of relations, that there remains between them only so much of a gap as is necessary to establish the line of separation.[22]

In the same volume he insists upon the equal antiquity of all real species, in the very passage in which he emphasizes the possibility of a wide range of variation within the species:

Though species were formed at the same time, yet the number of generations since the creation has been much greater in the short-lived than in the long-lived species; hence variations, alterations, and departures from the original type, may be expected to have become far more perceptible in the case of animals which are so much farther removed from their original stock.[23]

This is advanced as a partial explanation of the extreme diversity of breeds in the canine species: the dog is a short-lived animal and has therefore been capable of a relatively great degree of diversification.

A little later (in Vol. VI.,[24] 1756) Buffon declares that "nature

[21] These, the most definite and decisive words on the subject to be found anywhere in Buffon's writings, have been strangely disregarded by most of those who have discussed his attitude towards evolutionism. Samuel Butler can scarcely be acquitted of suppressing the passage, fatal to his theory. For he quotes in full the opening part of the passage, leaving off abruptly at the point where Buffon begins to introduce his serious objections to the theory of descent. Cf. "Evolution Old and New," p. 91.

[22] P. 59 (italics mine).

[23] P. 194.

[24] P. 55.

imprints upon every species its inalterable characters." In 1765—that is, at precisely the period during which we are told that Buffon "was expressing very radical views on the mutability of species"—we find him (in his "Second View of Nature," Vol. XIII.) giving his most extreme expression to the doctrine of the reality and constancy of genuine species. Here the language of the preliminary discourse concerning the relative significance in nature of the species and the individual has come to be completely reversed.

> An individual, of whatever species it be, is nothing in the universe; a hundred, a thousand individuals are nothing. Species are the only entities of nature (*les seuls êtres de la nature*)—perduring entities, as ancient, as permanent, as nature herself. In order to understand them better, we shall no longer consider species as merely collections or series of similar individuals, but as a whole independent of number, independent of time; a whole always living, always the same; a whole which was counted as a single unit among the works of the creation, and which consequently makes only a single unit in nature. . . . Time itself relates only to individuals, to beings whose existence is fugitive; but since the existence of species is constant, it is their permanence that constitutes duration, the differences between them that constitute number. . . . Let us then give to each species an equal right at nature's table; they are all equally dear to her, since she has given to each the means of existing, and of enduring as long as she herself endures.[25]

This sort of rhetoric is not the dialect of an evolutionist; it is almost that of a Platonist. And there is more in plainer language to the same effect:

> Each species of both animals and plants having been created, the first individuals of each served as models for all of their descendants. . . . The type of each species is cast in a mold of which the principal features are ineffaceable and forever permanent, while all the accessory touches vary.[26]

Many years later still, in 1778, there appeared the sub-division of the "Histoire Naturelle" which Buffon's contemporaries regarded as his most brilliant and most significant work—the "Époques de la Nature." This was a resumption on a grander scale, and upon new principles, of the task attempted in the "Theory of the Earth" in the first volume, thirty years before—an outline of planetary evolution. To the diffusion of evolutionary ways of thinking in the larger and vaguer sense, this treatise was a contribution of capital importance. Into the details of Buffon's geology I do not wish to enter in this paper. But it is worth while for our purpose to recall one or two striking facts about the "Époques." In it the writer, whom a recent German historian of biology has declared to have had a too little developed sense for the historical or genetic aspect of nature, attempted, in a far more comprehensive, more definite and more impressive way than any of his predecessors, to write the history of the gradual development of our planet from the time when, an incandescent ball, it was separated from the

[25] Vol. XIII., p. i.
[26] Vol. XIII., pp. vii, ix.

sun. The task was, of course, undertaken prematurely; but Buffon not only made the need of its eventual achievement evident, but also indicated two of the essential means by which it was to be accomplished: the study of present phenomena which can throw light upon the past processes through which existing conditions have been brought about; and the study of those natural "monuments which we ought to regard as witnesses testifying to us concerning the earlier ages." He insisted, moreover, with the utmost plainness upon (as it was then regarded) the extreme antiquity not only of the earth, but also of organic life. And in doing so he showed himself not at all disposed any longer to permit "revelation" to settle scientific questions. "How," he writes, "some one will ask me, do you reconcile this vast antiquity which you ascribe to matter with the sacred traditions, which give to the world only some six to eight thousand years? However strong be your proofs, however evident your facts, are not those reported in the holy book more certain still?" Buffon replies that he has all possible respect for scripture, but that it always pains him to see it used in this way. Doubtless there is no real conflict between its testimony and that of science; and he thereupon introduces what I suppose is the first of the long series of reconciliations of Genesis and geology. The six days were not really days, but long periods of time, and so forth. But in any case, he concludes, the Bible was originally addressed to ignorant men at an early stage of civilization, and was adapted to their needs and their intelligence. Its science was the science of the time, and ought not to be taken too literally. Finally, it is to be noted that in the "Époques" Buffon ceased to talk of the simultaneous creation of all species, and advanced the doctrine of the gradual appearance of different sorts of animals in conformity with geological conditions.

If, then, Buffon was desirous of inculcating the theory of the mutability of species, here was the place in which, above all others, he might be expected to do so fully and unequivocally. But here once more we find him reiterating the substance of his old doctrine:

> A comparison of these ancient monuments of the earliest age of living nature with her present products shows clearly that the constitutive form of each animal has remained the same and has undergone no alteration of its principal parts. The type of each species has not changed; the internal mold has kept its shape without variation. However long the succession of time may be conceived to have been, however numerous the generations that have come and gone, the individuals of each kind (*genre*) represent to-day the forms of those of the earliest ages—especially in the case of the larger species, whose characters are more invariable and whose nature is more fixed.[x]

By the "larger species" here, Buffon means those of greater size, such as the elephant and hippopotamus; and when he says that these are "especially" invariable, he means, as the whole context shows, not

[x] "Hist. Nat.," Supp., V., p. 27.

that any other species ever departs from its specific type, but that in these larger creatures even the "accessory touches" have been comparatively little altered.

Thus, in a long series of passages, from 1753 on, we find Buffon reiterating with explicitness and emphasis the same teaching, which has, for him, its principal bases in two of his most cherished conceptions: namely, in his conviction that the sterility of hybrids shows that species are real "entities of nature"; and in his embryological theory of "organic molecules" and of the "internal mold" which "casts into its own shape those substances upon which it feeds" and "can operate in the individual only in accordance with the form of each species." One of the first of modern naturalists to make the idea of organic evolution familiar to his contemporaries and to discuss it seriously, Buffon repeatedly rejected that theory, at all periods of his career; and he did so, not from timidity merely nor from an affectation of deference to scriptural authority, but upon reasoned grounds which he plainly stated and had every appearance of presenting as conclusive. Yet it is also undeniable, as will presently be seen, that he did not maintain this negative position without occasional waverings and doubts and at least one clear, though possibly inadvertent, self-contradiction.

3. In spite of his habitual emphasis upon the constancy of true species, Buffon insisted more than any of his predecessors, and more, perhaps, than any of his contemporaries, except Maupertuis and Diderot, upon the variability of organisms and the potency of the forces making for their modification.

> Though nature appears always the same, she passes nevertheless through a constant movement of successive variations, of sensible alterations; she lends herself to new combinations, to mutations of matter and form, so that to-day she is quite different from what she was at the beginning or even at later periods.[28]

The passage is from one of Buffon's later writings; but its close counterpart is to be found as early as 1756:

> If we consider each species in the different climates which it inhabits, we shall find perceptible varieties as regards size and form; they all derive an impress to a greater or less extent from the climate in which they live. These changes are made slowly and imperceptibly. Nature's great workman is Time. He marches ever with an even pace, and does nothing by leaps and bounds, but by degrees, gradations and successions he does all things; and the changes which he works—at first imperceptible—become little by little perceptible, and show themselves eventually in results about which there can be no mistake.[29]

For the most part these changes were clearly represented by Buffon as taking place only within the limits of species; they amounted merely to the formation of new "races" or varieties. Since his criterion of

[28] *Supp.*, V., 1778, p. 3.

[29] Vol. VI., pp. 59–60. I have borrowed Butler's excellent rendering of this passage.

identity of species (the possibility of interbreeding) did not essentially depend upon morphological similarity, he could with consistency suppose the descendants of a given pair to have departed to a very great (though not to an indefinite) degree, in the course of ages, from the form and external characters of their ancestors. It was, in other words, characteristic of his biological system that he set up an absolute distinction between species and varieties, gave an extreme extension to the notion of a variety, and sought to reduce the number of separate species as much as possible, by assuming—until the establishment of the sterility of the hybrids should prove the contrary—that most of the Linnæan species were merely varieties descended from a relatively small number of original specific types. Near the close of his essay "De la dégénération des animaux" (1766), Buffon writes:

> To account for the origin of these animals [certain of those found in America] we must go back to the time when the two continents were not yet separated and call to mind the earliest changes which took place in the surface of the globe; and we must think of the two hundred existing species of quadrupeds as reduced to thirty-eight families. And though this is not at all the state of nature as we now find it, but a state much more ancient, at which we can arrive only by induction and by analogies . . . difficult to lay hold of, we shall attempt nevertheless to ascend to these first ages of nature by the aid of the facts and monuments which yet remain to us.[30]

Here, clearly, is an evolutionary program, strictly limited by the assumption that there are irreducible ultimate species, yet tolerably ambitious: to regard all known kinds of quadrupeds as derived from thirty-eight original types, by modification in the course of natural descent; and to determine the general causes and conditions of the production of species in the ordinary sense, *i. e.*, of relatively stable varieties. These ideas occurred to Buffon too late to be made use of in his general plan for the classification of the quadrupeds; that plan, it will be remembered, was formed while he was unluckily under the influence of the principle of continuity. But in the volumes on birds, of which the first appeared in 1770, he had the opportunity for a fresh start; and he took advantage of it to introduce a method of distinguishing and classifying species which—within the limits already indicated—is expressly evolutionary in its principles.

> For the natural history of the birds I have thought that I ought to form a plan different from that which I followed in the case of the quadrupeds. Instead of treating of the birds . . . by distinct and separate species, I shall bring several of them together under a single *genus*. Except for the domesticated birds, all the others will be reunited with the species nearest to them and presented together as being approximately of the same nature and the same family. . . . When I speak of the number of lines of parentage, I mean the number of species so closely resembling one another that they may be regarded as collateral branches of a single stock, or of stocks so close to one another that they may be supposed to have a common ancestry and to have issued from that same original stock with which they are connected by so many points of resemblance

[30] Vol. XIV., 1766, p. 358.

common to them all. And these related species have probably been separated from one another only through the influences of climate and food, and by the lapse of time, which brings about all possible combinations and gives play to all the agencies that make for variation, for improvement, for alteration and for degeneration.[31]

Even the groupings which he gives, Buffon adds, can not be regarded, in the existing state of knowledge, as correctly and exclusively enumerating all the apparent species which are really akin to one another. The number of separate species which he lists, he intimates, is probably much too great. But at all events, he concludes with pride, his work is the first real attempt at an *ornithologie historique*.

The purpose of the present inquiry does not call for any extended exposition of Buffon's views about the causes of modification in animals and the ways in which quasi-species are formed. In the essay "De la dégénération des animaux" the subject is discussed at the length of over sixty quarto pages; the theories there advanced have been sufficiently accurately summarized by many previous writers. In brief, the factors in modification which he mentions as the most important are changes of climate (in which the most potent influence is temperature), changes of food, and the effects of domestication. But it is evident that he also believed in a general tendency to variation in the germ, and in the influence of acquired habits, of the use and disuse of parts, and of acquired lesions and mutilations. Thus he explains the humps, and the callosities on the knees and chest, of the camel and the llama as due to the habits of those animals under domestication. Similarly, the callosities on the haunches of the baboons arise from the fact that "the ordinary position of these animals is a sitting one—so that the hard skin under the haunches has even become inseparable from the bone against which it is continually pressed by the weight of the body." These theories, of course, take for granted the inheritance of acquired characters, which Buffon also (less cautious here than Maupertuis[32]) explicitly asserts. It is, I suppose, also well known that Buffon called attention (as Linnæus did independently) to the struggle for existence between species, due to the excessive multiplication of individuals, and pointed out how an equilibrium comes to be established (so long as external conditions remain constant) by means of this opposition.

It may be said that the movement of nature turns upon two immovable pivots—one, the boundless fecundity which she has given to all species; the other, the innumerable difficulties which reduce the results of that fecundity, and leave throughout time nearly the same number of individuals in every species.[33]

Buffon, in fact, rather over-worked this notion of a stable equilibrium, which rested upon the assumption of an approximate equality

[31] "Hist. des Oiseaux," I., 1770, preface.

[32] Cf. Lovejoy, "Some Eighteenth Century Evolutionists," POP. SCI. MONTHLY, July, 1904, p. 248 n.

[33] "Hist. Nat.," V., 1755, p. 252.

among species in their endowment for the struggle for survival. This is perhaps one reason why it did not occur to him to think of that struggle as causing a process of natural selection, or to see in it a factor in the formation of so-called species.

4. It must be evident to the reader from all that precedes that Buffon's mind, throughout nearly the whole of his life, was played upon by two opposing forces. Quite apart from any illegitimate and external influences, such as fear of the ecclesiastics—of which too much has been made—his thought was affected by two conflicting sets of considerations of a factual and logical sort. He saw certain definite reasons for regarding species as the fundamental constants of organic nature; what those reasons were has been sufficiently indicated. But he also saw that there was some force in the argument from the homologies; and—what in his case was still more important—he was committed to the program of explaining the diversities of organisms, so far as might be, by the hypothesis of modification in the course of descent; he was deeply impressed by the fact of variability; and he held to a theory of heredity (namely, of the heritability of acquired characters) which acted as a sort of powerful undertow towards a generalized evolutionism. Add to this that he was little careful of consistency and extremely careful of rhetorical effect—and it is not surprising that he occasionally forgot one side of his doctrine in emphasizing the other. There is one and, so far as I can discover, only one passage in which he seems categorically to contradict his ordinary teaching of the impossibility of the descent of really distinct species, sterile *inter se,* from common ancestors. This occurs at the end of the chapter on "Animals Common to Both Continents" (Vol. IX., 1761).

> It is not impossible that, without any deviation from the ordinary course of nature, all the animals of the New World may be at bottom the same as those of the Old—having originated from the latter in some former age. One might say that, having subsequently become separated by vast oceans and impassable lands, they have gradually been affected by a climate which has itself been so modified as to become a new one through the operation of the same causes which dissociated the individuals of the two continents from one another. Thus in the course of time the animals of America have grown smaller and departed from their original characters. This, however, should not prevent our regarding them to-day as different species. Whether the difference be caused by time, climate and soil, or be as old as the creation, it is none the less real. Nature, I maintain, is in a state of continual flux and movement. It is enough for man if he can grasp her as she now is, and cast but a glance or two upon the past and future, to endeavor to perceive what she may once have been and what she may yet become.

Here Buffon seems either to have forgotten or to have deliberately discarded his own usual criterion of diversity of species. He does not propose to inquire whether the American species are capable of having fertile progeny when mated with their respective congeners in the old world, but predicates difference of species solely on the ground of dissimilarity of form; and to the distinct species so determined he at-

tributes an identical origin. But it is possible that he has here merely lapsed (as he apparently does occasionally elsewhere) into the terminology in which he was brought up, and is using the word species in the Linnæan sense rather than in his own.

More significant, perhaps, than this possibly inadvertent inconsistency is the fact that, in his fourteenth volume[34] (1766), Buffon seems to raise explicitly the question—though only *as* a question—whether, after all, descent with modification may not extend to species as well as varieties.

> After surveying the varieties which indicate to us the alterations that each species has undergone, there arises a larger and more important question, namely, how far species themselves can change—how far there has been a more ancient modification, immemorial from all antiquity, which has taken place in every family, or, if the term be preferred, *in all the genera in which species that closely resemble one another are to be found.* There are only a few isolated species which are like man in forming at once a species and a whole genus. Such are the elephant, rhinoceros, hippopotamus and giraffe, which constitute genera, or simple species, and descend in a single line, with no collateral branches. But all other races have the appearance of forming families, in which we may perceive a common source or stock from which the different branches seem to have sprung.[35]

Even here one can not be wholly sure that Buffon is not referring to Linnæan species, and using the word genera to indicate what he usually means by species in the strict sense. Assuming, however, that he is speaking of "true" species, it must be observed that while he raises the question of their mutability, he does not answer it finally in the affirmative. For the passage is shortly followed by that cited earlier in this paper, in which Buffon, though he derives many species traditionally regarded as distinct from a common stock, yet finds even in "the first ages of nature" thirty-eight irreducible diversities of specific type among quadrupeds.

There is, however, one peculiarly interesting essay in which Buffon shows himself a little dubious even about that "most fixed point in nature" upon which his usual doctrine of the reality and constancy of species was based—namely, the fact of the sterility of hybrids. As I have already mentioned, this seemed to him so central a point in natural history that he for many years assiduously collected data concerning it, and caused experiments bearing thereon to be made and carefully recorded at his own estate at Montbard. The results of these inquiries, which he reports in the chapter "On Mules" (in the third supplementary volume, 1776), led him to the conclusion that hybrids are not necessarily without hope of posterity. On the testimony of an affidavit from a gentleman in San Domingo, Buffon declares that in hot climates mules have been known to beget offspring of mares, and females of their

[34] Just a year earlier we have found Buffon using the most exaggerated language possible about the changelessness of species.

[35] Vol. XIV., p. 335; italics mine.

kind to breed with horses. "One was therefore wrong formerly in maintaining that mules are absolutely infertile." Other experiments in the crossing of goats and sheep, dogs and wolves, canaries and goldfinches, are recited; they all go to show that sterility is merely a question of degree.

> All hybrids (*mulets*), *says prejudice,* are vitiated animals which can not produce offspring. No animal, *say reason and experience,* is absolutely infertile, even though its parents were of separate species. On the contrary, all are capable of reproduction, and the only difference is a difference of more or less.[36]

That hybrids are *relatively* infertile, and probably incapable of breeding with one another, Buffon still maintains; "their infecundity, without being absolute, may still be regarded as a positive fact." Something, therefore, is still left of his test of unity of species. But now that it seemed to be reduced to a mere difference in degree, it was no longer the sharp-cut, decisive, impressive thing that it had at first appeared. And, feeling that his criterion of species had a good deal weakened, Buffon was led—not, indeed, even now to an altogether unequivocal affirmation of the descent of real species from one another—but to a confused, half-agnostic utterance, in which he seems to take at least the possibility of such descent for granted:

> In general, the kinship of species is one of those profound mysteries of nature which man will be able to fathom only by means of long and repeated and difficult experiments. How, save by a thousand attempts at the cross-breeding of animals of different species, can we ever determine their degree of kinship? Is the ass nearer to the horse than to the zebra? Is the dog nearer to the wolf than to the fox or the jackal? At what distance from man shall we place the great apes, which resemble him so perfectly in bodily conformation? Were all the species of animals formerly what they are to-day? Has their number not increased, or rather, diminished (*sic*)? . . . What relations can we establish between this kinship of species and that better known kinship of races within the same species? Do not races in general arise, like mixed species, from an incapacity in the individuals from which the race originated for mating with the pure species? There is perhaps to be found in the dog species some race so rare that it is more difficult to breed than is the mixed species produced by the ass and the mare. How many other questions there are to ask upon this matter alone—and how few of them there are that we can answer! How many more facts we shall need to know before we can pronounce—or even conjecture—upon these points! How many experiments must be undertaken in order to discover these facts, to spy them out, or even to anticipate them by well-grounded conjectures![37]

This passage certainly indicates a strong inclination towards an acceptance of a thorough-going doctrine of descent; yet in Butler's lengthy compilation of the evidences of Buffon's evolutionism it is not cited at all! The volume containing it, says Butler, offers "little which throws additional light upon Buffon's opinion concerning the mutability of species"![38] In truth, it offers one of the best of the

[36] *Supp.*, III., p. 20; the italics are Buffon's.

[37] *Supp.*, III., 1776, pp. 32–33.

[38] "Evolution Old and New," p. 165.

extremely few passages which give some plausibility at least to the theory that Buffon was continuously working towards an unqualified transformism and actually arrived at that position in his later life. But if he reached it (which his language just quoted does not quite justify us in declaring) he did so only in a transient mood. For, as we have already seen, in 1779, in the "Epoques de la Nature," we once more find him asserting—though no longer upon the ground of the sterility of hybrids—that the "constitutive form" of each separate species is the same to-day as in "the earliest ages."

5. It is more important, and it is commonly easier, to determine what opinions a man's writings tended to encourage than to determine what opinions he actually held. Mind-reading is perhaps no essential part of the history of science. If, then, in conclusion, we raise the more important question with respect to Buffon, it is evident that his work both fostered and hindered the propagation of evolutionary ideas in biology. Earlier than any other except Maupertuis, he put the hypothesis of organic evolution before his contemporaries in a clear and definite form. He called to their attention, also, the facts of comparative anatomy which constitute one of the principal evidences for that hypothesis. Throughout the rest of the century we never cease to hear about the wonderful "unity of type" characteristic of the vertebrates and perhaps of all living things. It was this consideration which led Kant as near to evolutionism as he ever came; Herder and Goethe are full of it, though the former never admitted its full evolutionary consequences; and all, it is evident, learned it directly from Buffon. He, says Goethe, was the first to recognize *eine ursprüngliche und allgemeine Vorzeichnung der Tiere.* Buffon, moreover, once and for all inscribed upon the program of natural history, as its primary problems, the reduction of the number of separate species to a minimum, the derivation of highly divergent forms from a common origin through natural descent, and the discovery of the causes and methods of modification. He, finally, did more than any one else to habituate the mind of his time to a vastly (though not yet sufficiently) enlarged time-scale in connection with the history of organic nature, a necessary prerequisite to the establishment of transformism.

These were great steps in the progress of evolutionism. But it is equally true that Buffon probably did more than any other eighteenth century writer to check the progress of evolutionism. He did so partly by the authority which, for his contemporaries, attached to those personal utterances of his favorable to the doctrine of immutability. These utterances were far more numerous and more categorical than those which could be quoted on the other side; and they certainly were not taken as ironical by the average reader of the period. But, what is still more important, Buffon put into currency what passed for a scientific and serious argument against any wholesale theory of descent. In the

eyes of many learned men of his own and later generations, perhaps his chief single contribution to science was his definition of species. This, as I have recently pointed out,[39] was regarded as of immense importance by Kant, and was, indeed, the starting point and the controlling principle of that philosopher's biological speculations. "It is Buffon," wrote Flourens as late as 1844, "who has given us the positive character of a species." Now before the Buffonian criterion of species was propounded, there already existed a tendency towards evolutionism, fostered by the principle of continuity and by such embryological conceptions as those of Maupertuis—a tendency to disregard species altogether and to infer from the variability of individuals to an unlimited and rather promiscuous mutability of the successive generations of living things. If it had not been for Buffon, transformism would probably have developed at first[40] through the increase and diffusion of this tendency; and its development might well, in that case, have been more rapid. But when species came to be regarded as real "entities of nature," determined by the objective criterion of the sterility of hybrids, this somewhat too facile evolutionism received a check, and a certain presumption of the constancy of true species seemed to be created. This presumption had all the more force because it left room for a large measure of mutability in the case of varieties, and thus gave a sort of appeasement to the strong impulse towards genetic modes of thought which was already active in the mid-eighteenth century. But more than all this, Buffon, as we have seen, from the first managed to associate with his definition of species the assumption that the sterility of one kind of animal when crossed with another was a character that (unlike almost all others) could not have been produced in the course of descent with modification. And this supposition that the sterility of hybrids was incapable of an evolutionary explanation long remained a serious obstacle to the acceptance of the theory of descent, even with those little influenced by theological prejudices against the theory. We find even Huxley in 1862 troubled over the difficulty. In his Edinburgh lectures of that year "he warned his hearers of the one missing link in the chain of evidence—the fact that selective breeding has not yet produced species sterile to one another." The doctrine of descent was merely to be "adopted as a working hypothesis, . . . subject to the production of proof that physiological species may be produced by selective breeding."[41] Since Buffon appears to have been the first to emphasize the notion of physiological species, and to give currency to the supposition that the sterility of hybrids affords a presumption against any thorough-going transformism, he must be regarded as having done more than almost any man of his time to counteract the tendency which he also, perhaps, did more than any other to promote.

[39] Popular Science Monthly, January, 1911, pp. 37–38.

[40] Cf. Lovejoy, Popular Science Monthly, July, 1904, p. 248.

[41] Huxley's "Life and Letters," I., 193.

PROTOZOAN GERM PLASM

By Professor GARY N. CALKINS
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IN his classical essays on the nature of the germ plasm, Weismann, more than twenty years ago, drew a distinction between that protoplasm destined for the perpetuation of the race and that needed by the organism for its ordinary functions of moving, eating, digesting, etc. The former, which he designated germ plasm, in Metazoa is early differentiated from the latter, and in some forms may be distinguished as the rudiments of a germinal epithelium even before the end of segmentation. The latter develops into the vegetative organs of the adult and serves to nourish and support the former. The distinction, therefore, especially in the higher Metazoa, indicates a real difference in potential, and the vegetative cells have no primary reproductive functions. In lower Metazoa the distinction is not so clear, many of the vegetative cells turning to germ cells either in groups or singly.

Protozoa, or animals consisting of one cell only, were set apart by Weismann as differing from Metazoa in not showing this somatic germinal differentiation, and he regarded them all as potential germ cells. Furthermore, since germ cells have the possibility, at least, of continued life, while somatic cells die, he assumed that Protozoa are potentially immortal, while natural death is the penalty Metazoa must pay for the privilege of differentiation.

Weismann's hypothesis is certainly seductive, and, viewed superficially, would seem to indicate a fundamental difference between the unicellular and the multicellular animals. Protozoa, however, are more than mere single cells, comparable with the isolated tissue cells of higher animals. They must be regarded as organisms, complete in themselves and comparable, therefore, with the whole animal of higher type and not with any one of its cells. Like the entire Metazoon, it excretes the products of destructive metabolism, it secretes many different types of by-products; it moves, obtains food, swallows, digests and assimilates it through the action of digestive fluids; in short, it performs all of the functions which distinguish animals from plants. Finally, like higher types again it reproduces its kind by processes relatively as simple as the functions of digestion or nervous response are simple when compared with these functions in Metazoa. In such complete organisms, therefore, it is a logical inference to consider the protoplasm of a protozoon as made up of widely different elements

equivalent in function to the aggregate of cells making up the metazoon, and with some parts at least having the power to contract and move, some to digest food, some to secrete, others to excrete and still others, finally, to reproduce. Considered in this sense the cell theory as applied to the Protozoa is obviously inadequate.

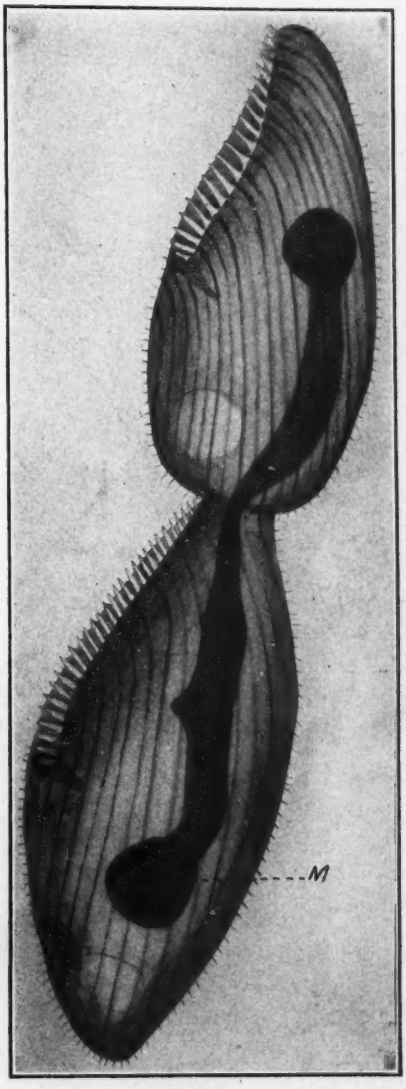


FIG. 1. *Original.*

The especial portions of the protoplasm that have to do with these several different functions of the protozoon can be identified in many cases as structurally different from the remainder, especially those parts which have to do with movement and with the perpetuation of the race, *i. e.*, the germ plasm. In the majority of Protozoa this portion of the protozoon is clearly differentiated, one time or another, from the remainder of the cell, and this justifies us in taking issue with Weismann, and with the majority of those who write casually about the Protozoa, as having no somatic cell elements and therefore no possibility of natural death. If it can be shown that there is a specific germ plasm in these unicellular animals, then the matter of immortality differs in no essential way from the same problem in Metazoa or Metaphyta where the germ cells have a possibility of endless existence. The evidence points to a common and universal law that continued life is an attribute of an especially endowed protoplasm, termed germ plasm, which forms the material basis of the reproductive cells.

The history of single Protozoa, if taken superficially, seems to point to the fact that the protoplasm of these cells does not die a natural death, but continues to live in successive generations of similar indi-

type corresponding with the hydroid, the macrosphæric type with the medusa generation. Like these cœlenterates, the microsphæric type reproduces asexually while the macrosphæric type reproduces sexually. Like them also, the asexual generation gives rise to the sexual and the latter, again, to the asexual, hence there is a typical alternation of generations. Like the cœlenterates, again, the sexual generation acts as a nurse for the important germ plasm. Let us see how this works out in the case of *Polystomella crispa.*

FIG. 4. *After Calkins.*

The young individual of *Polystomella* secretes a shell of calcium carbonate and grows by feeding on various minute animals and plants. Its nucleus divides by mitosis and the protoplasmic mass increases in size but does not divide with the nucleus. A new shell chamber is formed partly enclosing the first one. Further division of the nuclei, increase of the plasmic mass and new chamber formation continues with constant feeding until a typical *Polystomella* shell is formed, containing a relatively great protoplasmic mass and hundreds of nuclei. When mature, all of the nuclei save one or two break down into thousands of

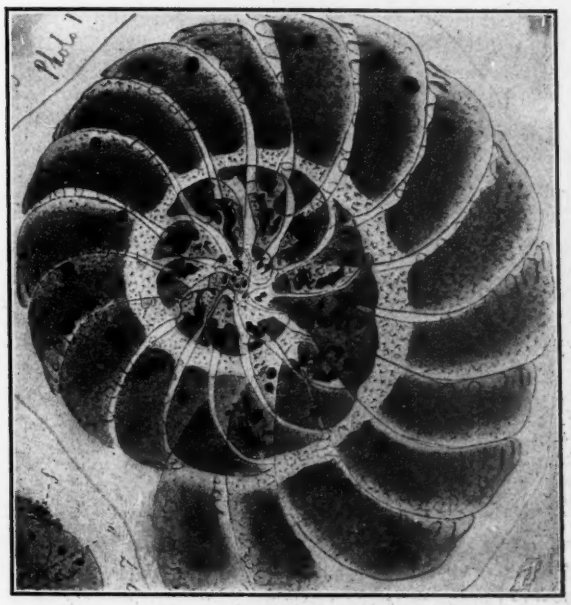


FIG. 5. *After Lister.*

minute particles of chromatin which are distributed throughout the protoplasm in the form of fine granules. Authorities differ somewhat in regard to the next changes of the nuclei. If we accept Schaudinn's

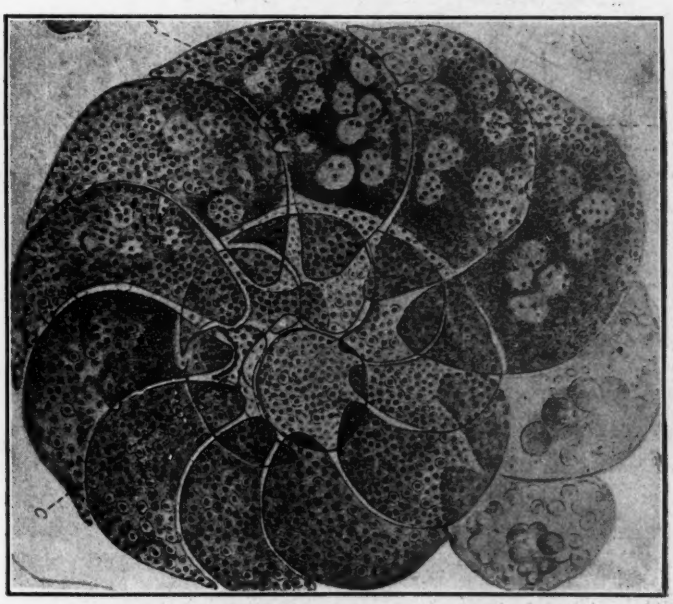
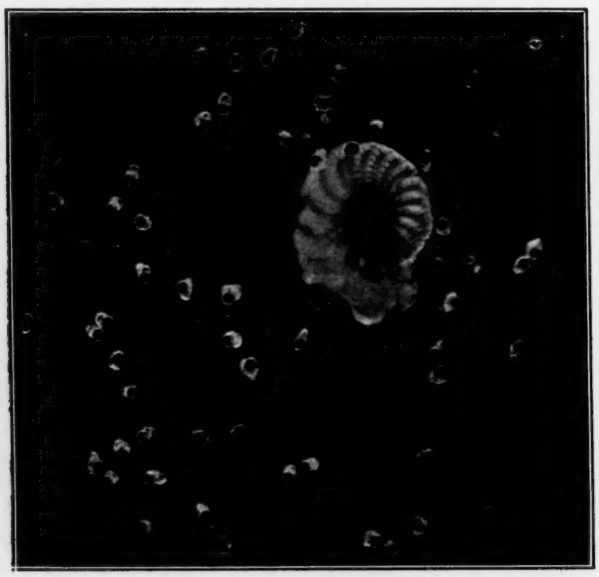


FIG. 6. *After Lister.*

account, verified by Winter, the protoplasm of the microsphæric individual breaks down into small fragments, each fragment enclosing a number of these granules of chromatin, which coalesce later to form one single nucleus. If we accept Lister's account the coalescence occurs before the breaking down of the protoplasmic mass. All observers agree, however, that hundreds of minute nucleated "embryos" arise



Photograph by J. J. Lister.

FIG. 7. *Polystomella crispa.* Liberation of pseudo-podiospores from the megalosphæric individual.

by fragmentation of the parent protoplasm (Fig. 7). The breaking down of the original nuclei is an important step, for by this process the important germ plasm is formed, which in the finely granular state described was named by Hertwig the chromidia.

The small "embryos" leave the parent organism in swarms (Fig. 8), and the calcareous shell is finally deserted. Each "embryo" then grows into a megalosphæric or large-chambered individual in which the primary nucleus remains single for a considerable period. New chambers are formed about the primary central chamber and a new adult individual results from the continued growth. The history of the nucleus, however, is quite different from that of the microsphæric individual. The protoplasm contains a large primary nucleus which ultimately degenerates and disappears. During life of the individual, however, this nucleus gives rise by chromatin "secretion" or by fragmentation, to an immense number of minute nuclei which are distributed throughout the protoplasmic mass. Each nucleus becomes

surrounded by a thickened zone of protoplasm and then each divides twice, thus increasing the number of the zones. All of the protoplasm is utilized in this zone formation, with the exception of a small portion surrounding the original "primary" nucleus, these parts degenerating and disappearing. Preparations of the decalcified individual at this period show hundreds of minute nucleated masses completely filling the shell space (Fig. 6). In life, these emerge in swarms, each in the form of a tiny bi-flagellated swarmer. The swarmers are gametes which

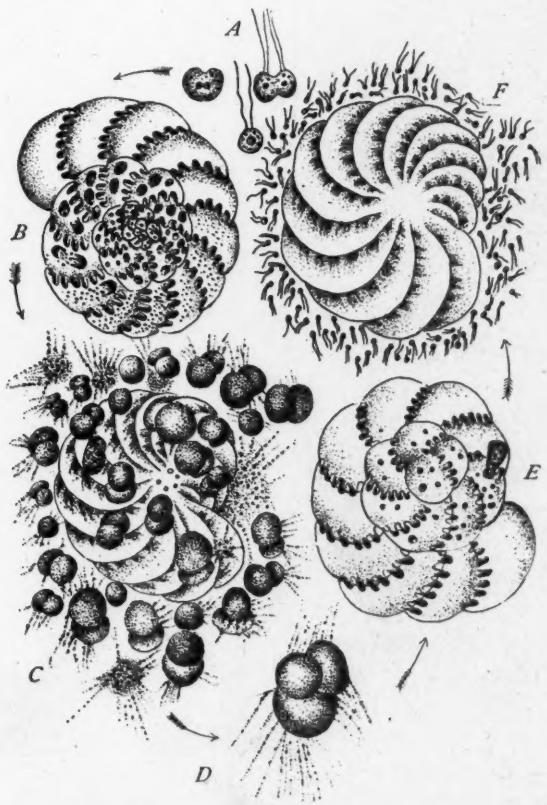


FIG. 8. *After Calkins.*

conjugate with similar gametes from another individual (Fig. 8, *A*). The flagella are thrown off after union, the nuclei unite, and each united pair, as a fertilized cell, or zygote, develops into a new microsphæric individual.

In *Polystomella,* therefore, fertilization is accomplished, not by union of the parent individuals as in *Paramecium,* but by coalescence and fusion of minute gametes which contain portions of the specific germ substance in the form of chromidia.

Arcella vulgaris, a common fresh-water shelled rhizopod, has a much more simple life-history. The nucleus of the young form soon divides, so that most *Arcella* specimens contain two primary nuclei (Fig. 9). From the very outset, furthermore, each nucleus secretes a chromatin substance which collects in a zone about the periphery of the cell. This substance is not granular like the chromidia, but has a similar origin from the nucleus, and has the same germ-plasmic fate as chromidia, so that Hertwig was justified in calling it a "chromidial net." When the organism is mature, minute nuclei condense out of the substance of this network, hundreds of them being formed (Fig. 10). As in *Polystomella,* each nucleus becomes surrounded by a zone of protoplasm, and, finally, a large number of small swarmers emerge from the shell mouth, leaving behind in the shell the two primary nuclei and a portion of the protoplasm as a degenerating residue. The swarmers are dimorphic,

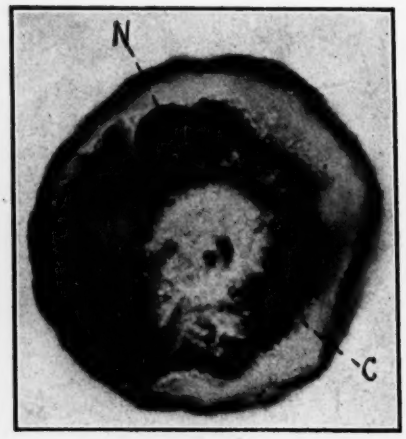


FIG. 9. *Original.*

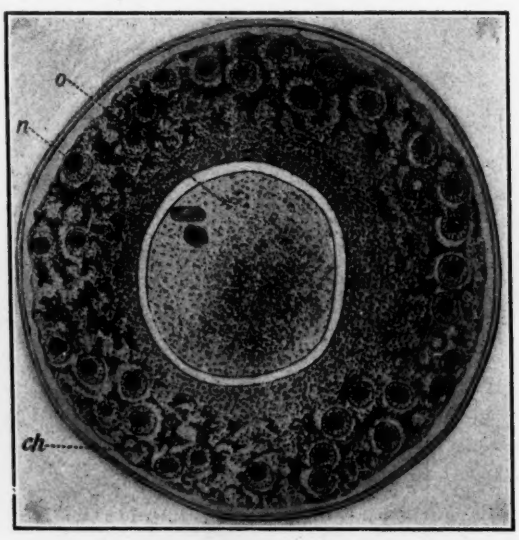


FIG. 10. *After Hertwig.*

some are macrogametes, some microgametes (Fig. 11). These fuse two by two, a macrogamete with a microgamete, and the resulting zygote develops into the normal form.

In *Arcella,* therefore, as in *Polystomella,* there is a definite germinal protoplasm composed essentially of chromatin which gives rise to new cycles of organisms, while a portion of the original organism, including the primary nucleus and a quantity of protoplasm, degenerates and dies. We can speak of germinal and somatic protoplasm in these cases, and with equal right in all of the thousands of allied species of protozoa, as well as in the case of any higher animal.

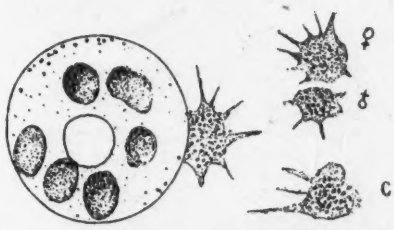


FIG. 11. *After Elpetiewsky.*

A still more interesting case of specific germ-plasm formation is given by a type of Gregarine belonging to a group of parasitic Sporozoa. In all of the Gregarines there is a segregation of the germ plasm and a residual somatic protoplasm which degenerates and dies a somatic death. One of the most striking illustrations of this type is the case of *Ophryocystis mesnili,* a parasite of beetles. Unlike the cases cited above, most of the gregarines do not reproduce asexually. *Ophryocystis,* however, is one of the exceptions to the rule, the individuals reproducing by simple division until the protoplasm becomes mature, when, as in *Paramecium,* two cells come together in conjugation. The single nucleus of each cell divides and one of the products becomes a "somatic" nucleus, to use Leger's term, while the other daughter nucleus in each cell divides again (Fig. 12, *A–G*). One of these corresponds to a polar body in the metazoon egg, the other is the gamete, or germ, nucleus. In each cell this nucleus collects about itself, possibly through the secretion of nuclear material which transforms the surrounding stuff, a denser zone of protoplasm, which, with the nucleus, forms a gamete within the body of the parent cell. The two gametes thus formed fuse while in the space which their formation has left in the parent somatic, or nurse cells. The latter ultimately wither up and die. After union of the two gametes, the sporoblast gives rise to eight germs or sporozoites, each capable of developing into an ordinary vegetative form when under the proper conditions of environment (Fig. 12, *H–N*).

Here in Gregarines, therefore, as in rhizopods, we see a clearly defined difference between germ plasm and somatic plasm, the latter dying, as in the Metazoa, the former capable of endless development. Unlike the rhizopods, however, the germinal chromatin is retained in the primary nucleus until full maturity of the cell and does not appear in the cytoplasm in the form of chromidia.

Turning after this excursion into other fields of Protozoa, to the

case of *Paramecium,* it will be seen that the conditions are entirely different from those which accompany conjugation in the majority of

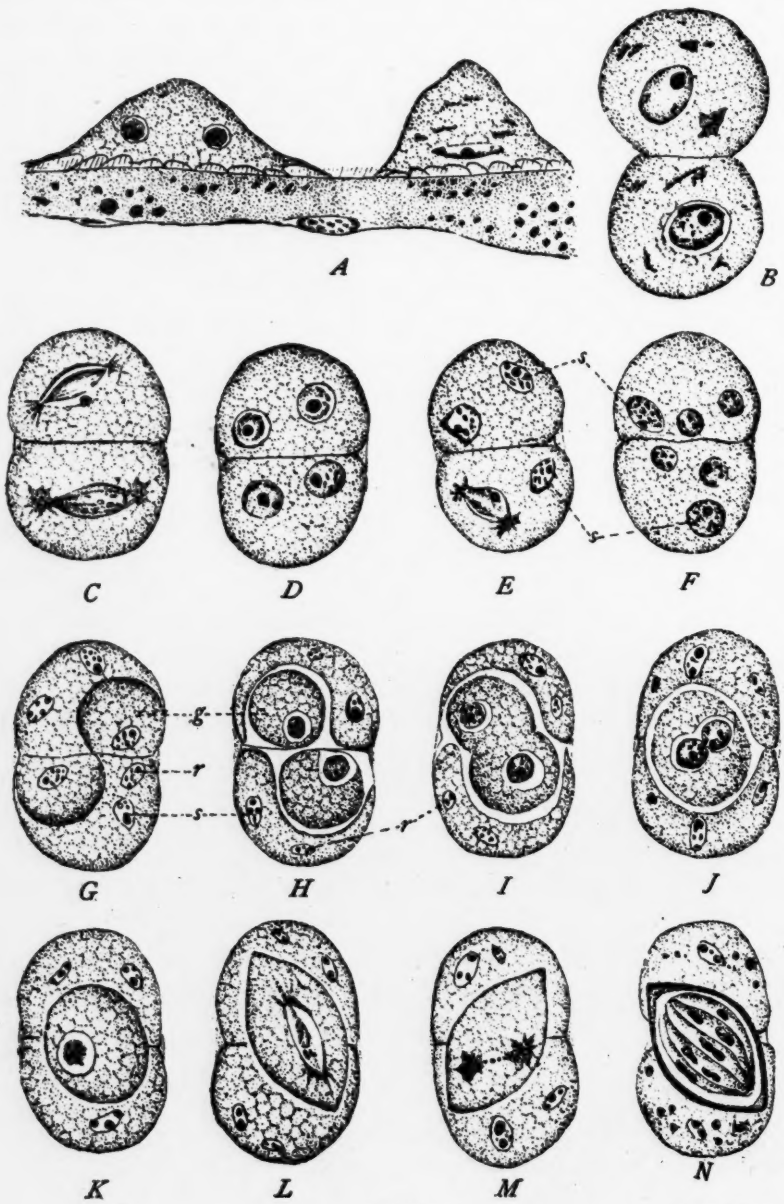


FIG. 12. *After Lèger.*

Protozoa. In the latter fertilization is accomplished by the formation and fusion of gametes or minute simulacra of the adult cells, some being differentiated into microgametes and macrogametes, or male and female.

In *Paramecium* there are no gametes of this kind, but portions of the adult individuals fuse as in *Ophryocystis mesnili.* Unlike this Gregarine, the fusion of the adult cells is only temporary and the two parties to the conjugation do not die. During the temporary fusion there is a mutual interchange of micronuclei and a mutual fertilization, while the only portion to disintegrate and die is the macronucleus of each conjugant, and this is replaced by a specially differentiated fragment of the new micronucleus.

In ciliated protozoa such as *Paramecium* and its near relations the germ plasm is concentrated in the micronucleus, while the somatic plasm is represented by the macronucleus. As we have seen, the micronucleus enlarges and divides during conjugation, first into two, then these into four, all but one of the four degenerating. The fourth divides for the third time, but this time unequally (Fig. 3) into a smaller migratory and a larger stationary form. The smaller micronucleus migrates into the other cell of the pair and there unites with the stationary larger nucleus. The macronucleus then degenerates and is absorbed in each of the conjugating cells.

The aberrant conditions in these Infusoria can be interpreted if we regard the three divisions of the micronucleus as the reminiscence of a

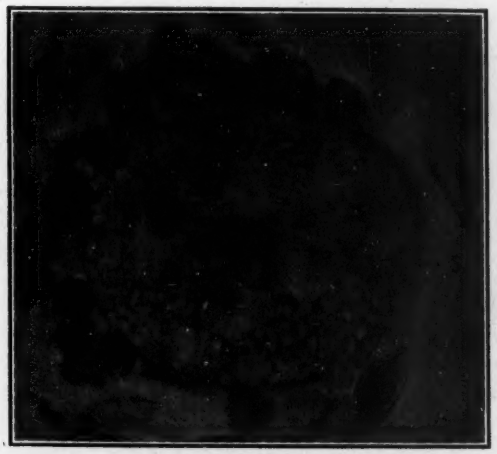


FIG. 13. *Original.*

process of gamete formation which obtained in remote ancestral forms. A parallel, but less extreme, case is seen in the Gregarine *Ophryocystis,* where one gamete only is formed by the conjugating cells. This is an isolated case among these Sporozoa, for in the typical forms a great number of gametes are developed, as shown in the accompanying photograph of *Monocystis* (Fig. 13). The one pair of gametes in *Ophryocystis,* plus the nuclear derivatives of the pro-conjugants, represent the

swarm of gametes found in other Gregarines. Here, also, the internal or "nursed" condition of the gametes is a new development or adaptation.

Similarly in *Paramecium* the three divisions of the micronucleus may be interpreted as representing an ancestral brood of conjugating gametes, only two of which are now functional, the one representing a macrogamete or female form, the other a microgamete or male cell. Unlike *Ophryocystis*, the *Paramecium* individual does not become a nurse for the conjugating gametes, but remains, as before, the mechanism for the performance of the various physiological activities and the vehicle of the somatic and germ plasms.

The widely accepted view, therefore, as first formulated by Weismann and repeatedly stated in general works on biology, that Protozoa differ from Metazoa in having no equivalent of the somatic cells and therefore no somatic, or natural, death, must be abandoned. In the vast majority of Protozoa there is a clearly defined equivalent of somatic cells and an equivalent of natural death. The conditions in *Paramecium* and its allies are different from those of other protozoa, the old individual does not die at conjugation but is completely reorganized and built up of parts derived from the product of fertilization exactly as in Metazoa. The protozoon is not a potential germ cell, but like the metazoon is the carrier of the racial germ plasm which, in the great majority of protozoa is differentiated from the somatic plasm. As the germ cells of the metazoon become segregated into a germinal epithelium, becoming functional at maturity, so the germ plasm of the protozoon becomes segregated as chromidia or granules of a specific kind of chromatin, in the cell and is likewise functional at maturity.

ADAMAS: OR THE SYMMETRIES OF ISOMETRIC CRYSTALS

By Professor B. K. EMERSON
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THE number 3, the first to have a beginning, middle and end, has always been sacred. We are all trinitarians. Four is the second prominent number. It is the first square. The strong man stands four square to all the winds of fortune. The combination of these in the number 7 has always had a peculiar mythical significance.

The triangle with the eye in its center is the symbol of Freemasonry. And we may see how far this triangle will symbolize the three changeless and four variable solids which together constitute the seven crystal forms of the isometric system.

The triangle has three points which are unique and three and only three unique forms—the octahedron, cube and dodecahedron find place in the three corners of this triangle at *a*, *b* and *c* (as shown in the plate), forms made of eight triangles: of six squares, or twelve diamonds, and these numbers are twice the number three, or twice the number four or the product of three and four.

We may refer the planes of all crystals to three equal rectangular axes and only three permutations can be made from the only non-variable parameters 1 and x, viz., $1:1:1$ for the octahedron, $1:1:\infty$ for the dodecahedron, $1:\infty:\infty$ for the cube—and so we reach the same result algebraically.

The three corners of the triangle are joined by three lines, each line made of a series of points which should symbolize each a linear series of cognate forms, and we have these three forms in the trapezohedron *d*, the three-faced octahedron *e*, and the four-faced cube *f*, each linking by a single unbroken series the three corner forms. These are placed each on its proper line on the diagram. They are each twenty-four-sided figures. In two, each side is an isosceles triangle, in one, a trapezium, a combination of two isosceles triangles.

The three-faced octahedron starts as a $3 \times$ 8-faced figure and ends as a $2 \times$ 12-faced figure. The 4-faced cube starts as $2 \times$ 12-faced form and ends as $4 \times$ 6-faced form. The trapezohedren starts as a $4 \times$ 6-faced form and ends as a $3 \times$ 8-faced form, the three-faced octahedron with which we began. This is expressed algebraically by the three formulæ $1:1:m$, $1:m:m$, $1:m:\infty$, which have a single variable parameter, and no additional similar formulæ can exist.

There remains the space of the triangle made up of points arranged in two dimensions, or in lines connecting any of the forms represented by the previous positions or formulæ with the center of the triangle.

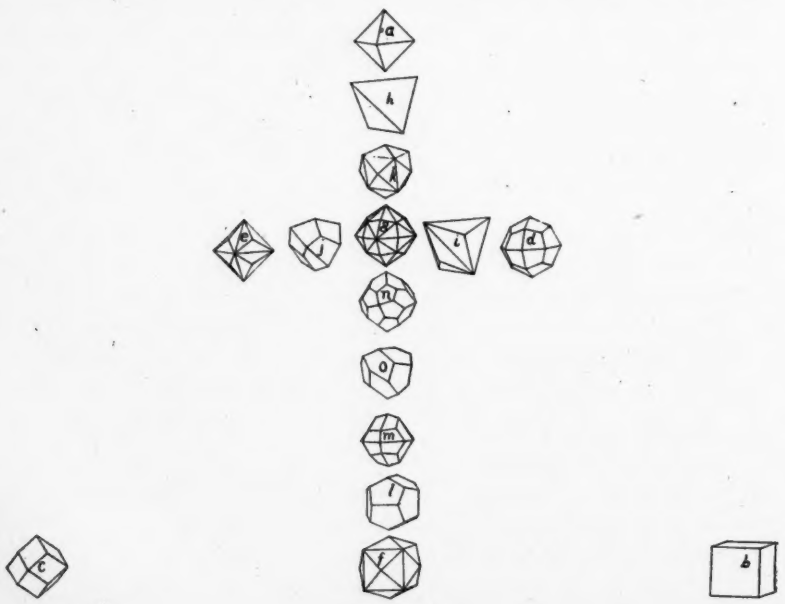
There is left a group of forms of a single type to occupy each point of this surface—the hexoctahedrons, and a sample of these is numbered

g on the diagram. As the space has two dimensions this has two variables, $1:n:m$. The first group at the corners of the triangle had faces with like sides, the second at the sides of the triangle had faces with two like sides, this third and last group has faces with unlike sides; they are scaline triangles. They have forty-eight sides, a number that can factor into 24, 12, 8, 6, 4 and 3. As they are arranged over the surface of the triangle, these nearest the octahedron are six-faced octahedrons in appearance, those nearest the cube are eight-faced cubes, those nearest the trapezohedrons are two-faced trapezohedrons, and so on.

For many years I have shown this symmetrical passage of these seven forms into each other by using three colors, red for the octahedral lines, blue for the dodecahedral, and green for the cubical, a device my old pupil, Geo. H. Williams, used in his "Elements of Crystallography." The upper corner is all octahedral, the middle horizontal band is half so, the base not at all octahedral, and so of the other corners symmetrically.

The law of symmetry permits any symmetrical half of these faces to appear independently on the crystal, and the crystal fulfils the law of symmetry, and this may be done in three ways. (1) We may take all the faces in half the octants, or half the faces in each octant, and in the second case we may begin in the second octant (2) with the face adjacent to the initial face, or (3) with a face not adjacent. In accordance with the first law the half of the faces of the octahedron forms the tetrahedron which we naturally place in the figure, as (h) directly beneath the octahedron from which it is derived.

In the same way the tetragonal dodecahedron (i), the half form of the three-faced octahedron, and the trigonal dodecahedron (j), that of



the trapezahedron, are placed beside their parent forms, and the hexatetrahedron (k), the half form of the hexoctahedron, is placed necessarily above the latter, from its relation to the tetrahedron.

In accord with the second law, the four-faced cube gives rise to the pentagonal dodecahedron (l) which is placed above it, and the central figure, the hexoctahedron (g) gives rise to the diploid (n) which is placed naturally just above its associate the pentagonal dodecahedron.

There remains the single gyroidal form (n) obtained by the third law, which is placed directly beneath the central figure (g) from which it was derived.

An inspection of the figure will show that the triangle with which we began, the mason's symbol of the trinity, has most naturally developed itself into the form of a cross. Isolated on either side stand the cube and dodecahedron, two unique forms not capable of change or conversion into any other form, like the two thieves beside the cross. But said one of my friends, who is a good crystallographer, as I called her attention to this similitude, one of the thieves *was* converted.

This would seem to throw doubt on the record, I replied, and yet there are infinite possibilities present, as one sees, in the formulæ, $1:\infty:\infty$, $1:1:\infty$.

One observes next that the five Platonic forms find symmetrical place on the figure: two at the top, two at the lower corners and one—the icosahedron—by evenly balanced combination of the top and bottom of the figure. $111, \frac{12x}{2}$.

The cross may be a cross of gold or of any other of the noble metals, and an inspection of the figure shows further that it culminates in an upper triangle placed like a crescent above the cross which contains the perfect forms attained by the perfect mineral, the diamond. At the center of this triangle is the tetrahedron (h) which gives the model of the atom of carbon and the hexatetradon (k) the most typical form of the diamond itself.

So again in a new arrangement of the elements in accord with the periodic law, proposed by the writer,[1] carbon is the culmination of the first octave and the very center and omphalos around which all the elements circle in their grand evolution. It has four-fold valence and threefold allotrophism and stands as the center of the seven elements of the first octant. And as the diamond is brought down from the heavens in the meteorites and brought up from the depths of the earth with the deepest rocks, and as it is endowed with the greatest power over light and over all solid bodies, so it presents in its almost spherical hexatetrahedron a mean around which the earth seems many times to have oscillated, as Arldt has shown,[2] now varying slightly toward the tetrahedron; now almost recovering again the spheroidal form.

[1] "Helix Chemica," *Am. Chem. Jour.*, Vol. XLV., p. 160, 1911.

[2] Dr. Theodor Arldt, "Die Entwickelung der Kontinente," Leipzig, 1907.

THE LACK OF PRINTING IN ANTIQUITY

By FREDERIC DREW BOND

AMONG fragments from the Græco-Roman world which have come down to us, not a few imply the use of some sort of stamping, or rudimentary printing. Seals and stamps bearing reverse legends are not infrequent, and, in 1908, the Italian Archeological Committee at work in Crete discovered a terra-cotta inscription whose letters had been impressed separately. According to Lacroix[1] Cicero had at least the idea of movable type, for in arguing against the Epicurean conception of the world as formed by the chance concourse of atoms, he uses this curious line of reasoning: "Why not believe, also, that by throwing together, indiscriminately, innumerable forms of letters of the alphabet, either in gold or in any other substance, one can print on the ground with these letters, the annals of Ennius?"

D'Israeli in his "Curiosities of Literature" has a quaint passage in which he suggests that the Roman Senate, fearing the effects of printed books, prevented movable type from coming into use. Another suggestion is that of De Quincey, who expresses the view, which he states he derives from Archbishop Whately, that the reason the Romans did not use the press was not from lack of knowledge of movable type but from lack of paper with which to make use of it. The ancients, as is well known, used not paper, but papyrus, on which to write. Shreds of this river plant (which, according to the Encyclopædia Britannica, still grows in the Nile valley) were split apart in long pieces, interwoven with one another and the whole then heavily pressed till a smooth and polished surface suitable for writing was obtained.

But though lack of paper might have impeded the development of typography in antiquity, had its invention, otherwise, been feasible, this does not seem to have been the main cause accounting for its absence. For, after the fall of Samarcand in 704, the Saracens became acquainted with the manufacture of paper and, also, no doubt, learned of block printing among the Chinese; yet printing did not appear in the caliphates of Arabia or of Spain any more than it did among the Romans. (Among the Chinese, needless to say, it was the multitude of written characters which prevented the development of typography from block printing.) It may be thus suspected that printing was wanting in the Roman Empire for much the same reasons that it was wanting among the Saracens. By the end of the first century of our era there were already written nearly all the works which we call classics and a num-

[1] "Arts in the Middle Ages," English translation, p. 486.

ber of each large enough to supply the reading demand had been turned out in manuscript. The literary output of new works in the Roman Empire was, from our modern standpoint, extraordinarily small. Aside from a few romances nothing existed in prose which would fall under our head of fiction. More than this, the output of scientific, descriptive and even historical writings was scanty in the extreme. Poetry, satire, philosophy and religion seem to have made up the greatest part of the output of new books in the Roman shops. Reading never became in the Roman Empire the necessity it has been to an educated man for many centuries past. Those who read habitually in the empire were the school children and scholars, and the wants of these last were supplied by the great libraries of Alexandria, Athens and Rome. Reading and writing were to others rarely more than a means of communication and of casting accounts or other commercial business.

Nevertheless, had printing been invented in the Roman Empire it would, no doubt, in the end, have created a demand for the books which it would almost certainly have called into being. Now the idea of typography, to nations possessing an alphabet, is so obvious that its failure to appear at all in Rome seems at first puzzling. Commercial enterprises are frequently started with no more prospect of gain than a printing office, if ready for work, would have faced in Rome. The real reason why in the conditions in the Roman Empire printing did not appear at all is revealed when we turn to the history of the early printers who invented the art in the fifteenth century. Though the idea of typography is obvious, the means first to make the idea actual were, we find, very far indeed from being so. Obscure though the early history of the art is, it is certain that effort after effort was made by several small groups of men in Holland and on the borders of Germany to make a commercial success of printing in the years between 1420 and 1450. The difficulties they encountered were manifold—a workable ink, a press which would give even impressions, but, most of all, type, both as regards its cutting or its casting and as regards its wear, we find giving them endless difficulties. We get some idea of the labors connected with the invention when we find Gutenburg trying to print at Strasburg as early as 1436. About 1442 he went to Mayence. There he exhausted his means in various experiments. In turn he took up and laid aside the different processes he had tried—xylography, movable types of cast iron, wood and lead. He invented new tools and experimented with a press made on the principle of a wine-press. He began work on nearly a dozen books and could finish none of them. In 1450 he entered into partnership with John Fust, a rich goldsmith of Mayence. Fust agreed to advance Gutenburg 800 gold florins for the manufacture of implements and tools and 300 for other expenses. In 1451 Peter Schoeffer, an employee in the establishment, at last hit on a

commercially feasible method of casting type. This discovery, which enabled printing to become a business success, he communicated to Fust, and the two, after getting rid of Gutenburg by a legal device, then printed the famous "Great Bible" of 1456.

The story of the invention of printing thus shows clearly that without a strong money-making stimulus, the years of thought, labor and expense necessary to make a business success of the art would not have been hazarded. This money-making stimulus existed in the fifteenth century but was lacking in ancient times. The first printers came on the scene at the beginnings of the renaissance, when in Germany, where the awakening took a religious direction, there was a strong commercial demand for bibles and works of devotion, which was not supplied by the manuscript output. Moreover, eager readers for the literature of Greece and Rome and for the writings of the Church fathers could be found in every European country touched by the early Renaissance. This antique and religious literature and the bible, in the Vulgate and in translations, furnished the materials for the first printers till the controversies of the Reformation brought more grist to the mill. Between 1456 and 1478 the new art had been exercised in Germany, the Netherlands, Italy, France, Spain and Scandinavia. By the beginning of the sixteenth century it is computed that 16,000 editions of books had been printed.

On the other hand, in the Roman Empire, the popular old books were already in sufficiently large manuscript circulation and what there was of new material was amply cared for by the few publishing houses of Alexandria and Rome. In the Roman Empire the demand either for new books or for new copies of the old was too well supplied for inventor after inventor to take up some thirty-five years in perfecting movable type. It was the insight that the demand for more books would afford great gain if gratified which induced the long labors which ended in a practicable method of producing and using movable type. No such prospect existed in antiquity. To a Roman of the Empire a printing press would have seemed a commercially useless contrivance.

Whether, of course, fragmentary printing with some rude and easily produced sort of movable type, such as would be made of carved wood, ever occurred at all in ancient times can not be said. Not improbably, it did; the Cretan inscription, noticed above, had it been impressed on papyrus by ink, would have been an example of rudimentary typography. Possibly, for all we know, attempts of this sort, made for the amusement or for the novelty of the thing, may have occurred time and time again.

IS VEGETARIANISM CAPABLE OF WORLD-WIDE APPLICATION?

By Professor ALONZO ENGLEBERT TAYLOR

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VEGETARIANS are to be classed into four groups:

Vegetarians from motives of gustatory taste.
Vegetarians from motives of esthetic taste.
Vegetarians from motives of physiological opinion.
Vegetarians from motives of ethical opinion.

Some individuals, particularly in youth and in advanced years, dislike the flavor of flesh. Esthetic vegetarianism is common; and much that in the minds of the adherents of this exclusive diet is regarded as physiological opinion is really esthetic revulsion. The publication of the "Jungle" made many converts to vegetarianism. The centralization of slaughtering has intensified the natural aversion to the process, since, in addition to the lack of hygienic precautions that once prevailed in the large packing houses, the mass of gore as exemplified in the large establishments multiplies the esthetic revulsion. This is due to a trait in human nature familiar to every psychologist and sociologist. It has been difficult to arouse in this country a proper general appreciation of the extent of the yearly loss of life due to preventable dangers of machinery. The daily deaths among employees, here and there geographically, does not impress the public mind. But when through a defect of machinery a score of lives are obliterated in a wreck, the public is appalled.

Vegetarians from motives of supposed physiological opinion are very numerous. The physiological reasoning of the majority of these individuals is not based upon a study of physiology in any sense of the word. It is too often merely an expression of that license of democracy, according to which in this free country everybody feels the right to a definite opinion on every subject, without having studied it—a license almost as widely utilized by the college-bred as by the uneducated man, and contrary to common prejudice as widely utilized by men as by women. To the individual adherent of this school of vegetarianism, the exclusion of flesh from the diet is based upon the conviction that it is harmful to digestion or inimical to nutrition. A sense of personal experience (often purely esthetic, sometimes merely an idiosyncrasy, at times imaginary) is all too easily expanded into a generalization in the untrained mind. That the contrary experience can occur is made evident by the reported instance of a young man in the Alps who from

childhood has lived solely on milk, excluding all meats, vegetables and fruits. The physiological vegetarian is usually inconsistent, in that milk, cheese, butter and eggs are not excluded, and very often meat stocks and animal fats are used in the cooking of vegetables. Reference will be made later to the physiological grounds upon which consistency in this matter is to be judged.

Philosophical vegetarianism rests upon the simple ethical proposition that man has no right to preserve his existence, enlarge his comforts or advance his material and spiritual welfare at the expense of the life of animals. Animals of all classes are to the ethical vegetarian, as in the Indian religion, as fully entitled to life as man; the commandment "Thou shalt not kill" is interpreted to apply generally to all types of animal life, and the slaughter of animals for the service of man is regarded as an expression of brute force which is inhuman. There is in this proposition an ethical appeal which finds response in every heart. The historical opinion of mankind, outside of India, holds that the right of man to kill animals is one vested in the higher moral and mental position of man among the animals, grounded in a higher importance in the broadest sense. The right to kill animals is, however, quite universally confined to instances in which higher human needs are positively and directly advanced. Needless killing is by all cultivated peoples condemned (if less consistently in practise than in theory) and the advance from savagery to civilization has been characterized by progressive cultivation of the regard for life. Our societies for the prevention of cruelty to animals and the Audubon societies are the public expressions of the ethical feeling that we owe it to animals, and to ourselves, to protect animals from suffering and from indiscriminate and purposeless slaughter. But deeply rooted in the minds of the mass of cultivated ethical men and women is the conviction that mankind has the right to be fed and clothed at the cost of the lives of animals; the domestication of animals is held almost universally to include the right of slaughter as well as the right of service.

To be consistent, the philosophical vegetarian must not only abjure the use of flesh in the diet, he must also abstain from the utilization of products of animal bodies, the procurement of which entails the death of the animal. Thus his articles of clothing, personal effects, household furnishings and implements of trade and occupation may bear no stain of blood. It is wholely inconsistent in one who keeps the hands and feet warm with the skin of an animal to reproach another for keeping the body warm by the use of meat as a fuel. Other fuels are truly available; so are other means for the retention of the heat of the body; the skin of man has no privilege above the other tissues of his body. The Indian soldier who refused to use ammunition greased with beef suet was entirely consistent. That it may be easy to feed the human

body on food other than flesh and difficult to clothe the human feet without leather can have no bearing on the ethics or logic of the question. If man has the right to kill animals for his use, what is to constitute *necessary* use will always remain a matter of more or less individual judgment, as the movement for the protection of bird-life clearly illustrates. An aigrette may seem more necessary to the woman of fashion than are leather shoes to her less evolved peasant sister. From this point of consistency therefore no departure can be permitted. Here the consistent vegetarian and the consistent anti-vivisectionist meet, both resting the ultimate argument upon the broad proposition that man has not the right to nourish himself, clothe himself or save his life at the expense of the life of an animal. On the other hand, consistency does not demand of the ethical vegetarian, as of the physiological vegetarian, the exclusion of milk, cheese, butter and eggs from the diet. Although the slaughter of animals is from the ethical point of view condemned, the domestication of animals for their service is not excluded, since it can be easily shown that domestication yields to animals security from beasts of prey, protection from the elements and provision for food beyond the natural expectations, thus tending to prolong life as well as to promote the well-being of the animals. The ethical vegetarian is not concerned with physiological opinions bearing on the healthfulness of plant as against animal albumin, just as the consistent anti-vivisectionist is not concerned with the question whether vivisection has resulted in knowledge that leads to the alleviation of human suffering, the cure of human disease and the prolongation of human life; even though animal flesh be the most healthful of foods, even though vivisection lead to the cure of human disease, man has no right to these at the cost of animal life.

When now we turn to the modern science of nutrition, and ask the question: Is a vegetarian diet physiologically correct, adapted to the best purposes of a normal life, capable of sustaining the highest standards of growth, health, endurance and longevity? We receive a reply couched in no uncertain terms. Yes, a properly selected and prepared vegetarian diet meets completely the highest requirements of a diet. The technical reply to the question, stated in untechnical terms, would yield something like the following elucidation of the dynamics of nutrition. The three main classes of foodstuffs are sugars (including starches), fats and albumins, using the last word to correspond to what the physiologist terms protein. Since the fats and sugars, whose rôle is largely that of fuel, are interchangeable to a large extent, and since the vegetable fats are in every respect equivalent to the animal fats, the question of the adaptability of a vegetarian diet resolves itself into the concrete question whether plant albumin is the equivalent of animal albumin as tissue-builder. The chemical investigations into the con-

stitution of albumins, carried out largely during the past two decades, have taught us that albumins are composed of simpler substances, termed amino-acids; the different native albumins are composed of many amino-acids in different proportions; and all the chief plant and animal albumins are in general composed of the same amino-acids, though in different proportions. These amino-acids we term the "building-stones" of albumin, and, as stated, the plant albumins contain all the essential amino-acids, the same building-stones that are contained in the animal albumins. When an albumin is digested, it is split (torn down) into the component building-stones. These building-stones are then absorbed, and with these the body, displaying a specific biological selection, builds or forms its own peculiar albumins. In other words, the building-stones are common to all albumins, the chemical and biological differences in the albumins rest in the architecture and not in the building-stones. Many types of houses may be constructed of brick of a common type; and so many kinds of albumin are formed of building-stones of common types; and from the common albumins of plants all the building-stones needed in the formation of the human albumins are to be obtained. It is clear therefore that it is quite immaterial to the human body whether it forms its tissue albumins from amino-acids derived from the digestion of animal or plant albumin, *i. e.*, these are equivalent in their nutritive values. These purely physiological and chemical data, abundantly sustained by laboratory researches and animal experimentation, confirm as well as elucidate the now widely made human experience that a properly selected and prepared vegetarian diet is a complete diet for all conditions and periods of life, beyond the lactation term of infancy.

Is a purely vegetarian diet better than a mixed diet, a diet containing a reasonable amount of albumin of animal origin? To make the question physiologically fair (since meats are often hugely overeaten), the ration of albumin in the two diets must be such as scientific investigations have shown to be sufficient and normal. Possibly a gram of albumin per kilo of body weight per day (equivalent to eleven ounces of meat per day for a body of 150 pounds) may be accepted as the normal total ration of albumin. There are absolutely no data of scientific nature or reliable observations in practical experience tending to show that either of these diets is in any way preferable physiologically to the other. It is apparently immaterial to the body of a hundred and fifty pounds whether in a properly selected and prepared diet the 2.2 ounces of albumin are exclusively of plant origin or partly derived from flesh. Since all cereals and vegetables contain albumin, a mixed diet always contains both plant and animal albumin, the ration of the latter of which would naturally run six to eight ounces of meat per day. I have used the words properly selected and prepared. It is obvious that

the meats must be free of decomposition and properly cooked. It is on the other hand, possible for a vegetarian diet to disagree, if, as is often the case, the attempt is made to derive the larger part of the needed albumins from the legumins, peas and beans. For the vegetarian above all others, bread is the staff of life, and cereal albumin must remain the chief dependence of the consistent vegetarian.

Modern physiology then teaches that there is no demonstrable basis for the so-called physiological vegetarianism. It teaches further, however, that the assumed distinction, made for the convenience of arbitrary vegetarians, between the flesh of animals and the albuminous products of animals (milk, cheese and eggs) is unfounded. The casein of milk and the albumin of the egg are as distinctive and specific biologically as are the muscular tissues of the animals from which they are derived. Every reason advanced, or assumed to exist, opposed to the use of beef as albumin for the human diet must hold with equal force against the use of casein of the cow's milk; every argument against the breast of chicken must hold against the egg of chicken. As a matter of fact, as stated above, there is no physiologically valid argument against either beef or casein, against second joint or white of egg.

Since it is apparent that physiological vegetarianism is merely a scientific error and that vegetarians from gustatory taste or from esthetic considerations are merely instances of arbitrary individualism, ethical vegetarianism alone remains to be considered. This is in its tenets and conclusions a logical system. Is it susceptible of consistent, world-wide application? We will not attempt to discuss the large question as to man's relations, biologically and ethically, to the lower animals, concerning which the Christian and Buddhistic teachings are diametrically opposed. Assuming that the system were rigidly and consistently applied to the entire population of the earth, two main problems would be presented.

Is the production of plant albumin on the earth sufficient to meet the albumin needs of the earth's inhabitants?

What transformations would result in the customs, industry and commerce of the world, in the sociology and economics of the nations of the earth?

Before these two questions can be discussed, we must be clear as to exactly what would be demanded in the carrying out of consistent ethical vegetarianism. It would be permissible to domesticate animals, to employ them in service and to utilize the products of their life. It would not be permissible to kill animals either for food or for the products of their bodies. The use of milk, butter, cheese and eggs would be permitted; the utilization of fur and leather would be excluded. An exception might be claimed in the case of leather, that it would be permissible to use the pelts and hides of animals that had died of old age

and of natural disease. Practically, however, this would be of little difference; the leather made from the hides of animals dead of old age would be of so low value as to be almost worthless; and the use of the hides of animals dead of disease, many forms of which are infectious and communicable to man, would be fraught with danger and difficult of execution. Mankind would have to face the problem of clothing without the aid of leather and fur.

Can the surface of the earth (for the fishes of the sea would have to be excluded) raise enough grain, fruits, nuts and vegetables, added to dairy products, to meet the albumin needs of the present earth's population? Unhesitatingly it may be stated that the area of the earth's surface now under cultivation could not, with the present methods of agriculture, dependably produce enough plant albumin to meet the needs of the present population. Very large areas of the earth's surface at present produce only grasses, shrubs and trees. Man can neither graze nor browse. At present these plants are consumed by cattle, goats, sheep and swine, whose albumin is utilized in turn by man. It is through the mediation of these animals that the vegetation of enormous areas of land is made available for mankind. At present probably one half of the albumin needs of mankind are met by animal albumin. To meet these needs with plant albumin and dairy products the world's production of grains and legumins would need to be doubled at the least. It is quite certain that this could not, with the uttermost efforts of the world's population, be dependably accomplished at present. It is possible that it might be accomplished, with the present methods on the present acreage of tillable soil, if no untoward manifestations of the elements occurred (such as severe winters, unseasonable frosts, floods, droughts, storms, excessive heat), with a dependable rain-fall in both time and space. But mankind would be yearly at the mercy of the elements. To meet fully and safely the needs of the growing population, four scientific advances of monumental magnitude would need to be attained.

The methods of the cultivation of the soil must be so intensified and revolutionized through scientific investigations as to make the yield of the soil less disproportional to its potential.

The conservation of water must be accomplished on a scale never before dreamed of.

The world-wide ravages of the parasitic diseases of plants must be checked.

The conversion of inert atmospheric nitrogen into potential soil nitrogen must be accomplished upon a vast scale through microbic and electro-chemical agencies.

The results of the accomplishment of these four advances, judged merely from present scientific knowledge of the possibilities in the four

directions, would result in quadrupling the yield of the present area of cultivation, and in transferring to the state of cultivation vast tracts now untillable or even waste. The difficulties would not be technical, but human. To accomplish them the present intelligence of the human race, the dependable intelligence of the working race of mankind, would be wholly insufficient; the race has not attained to-day the scientific stature necessary to reach and pluck these fruits of knowledge. For the present, therefore, it is certain and beyond speculation that to place the human race upon the basis of ethical vegetarianism would be to expose the race to the mercy of nature, just as the vegetarian population of India is yearly at the mercy of the yield of grain.

To dispense with the products of animal bodies would be a task trivial in comparison with the problem of feeding. With wools, cottons, linens and the other plant fabrics, with metals and woods, all could be accomplished without great technical difficulties, were preconceptions once obliterated. From the standpoint of ethical vegetarianism, the wearing of fur, kid gloves and leather shoes constitutes fratricide. The number of animal and bird lives sacrificed to-day for purposes of superfluous comfort and for compliance with the vanities of fashion makes a striking numerical showing contrasted with the number of animals slaughtered for the supply of food. The difficulties would lie in clothing the extremities of out-door workmen; but the problem would be solved without difficulty in a world rich in inventive devices though poor in large scientific conceptions.

The results of the world-wide installation of vegetarianism to the sociological and economic institutions of the world need but to be sketched to be appreciated. The race of swine, as a domesticated family would be obliterated, and the number of cattle regulated by the requirements for dairy products. On the other hand, the number of horses would need to be augmented to meet the needs of enlarged agriculture; and the number of sheep to meet the increased demands for wool. The population of the world would tend to shift in latitude, and the commerce of the world would be revolutionized to meet the alterations in the currents and articles of trade. Fashions in dress and house furnishings would be strikingly changed. There is no need to dilate further upon these features. Man is to-day a beast of prey. Just as the whole map of biology would be changed in the day when "the lion and the lamb shall lie down together," so the whole face of civilization would be given transformed features in the time when man regards the animal as a brother and not as a prey. Man is a beast of prey because thus the preservation of existence is made easy; vegetarianism would make it difficult, and will therefore not be adopted. This carries its personal lesson: I, the vegetarian, must not be vain; because it is the meat-eating of my brother that makes vegetarianism possible to me.

A BUGBEAR OF ECONOMICS

By Professor HERBERT ADOLPHUS MILLER

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IT seems to be peculiarly difficult for men, whether in science, politics or religion, to give up a law or doctrine which has become a slogan to them, after it can no longer be justified. This is true of the law of diminishing returns which economists have considered to be fundamental to much of their reasoning. I have been able to find but one prominent economist of the present day who has made any definite attack upon this "law."

Simon N. Patten, in the "New Basis of Civilization" says:

> The law of diminishing returns was discovered by the most stupid body in England—a committee of the House of Lords. English agriculture at the close of the Napoleonic wars was so abnormal that any one could see how the high price of food brought poor land into cultivation. A committee, even if it was stupid, could not but stumble on the pertinent facts that formulated the law. But their perception of it does not account for its subsequent vogue. The real question of control is, Why did a nation, naturally optimistic and in a period of rapid industrial advance, accept the hopeless doctrine and permit it to curb their thinking for generations? Why also do teachers in America, where notoriously it never has been in operation, hold devoutly to it and spend their time expounding a lame philosophy to their classes?

Professor Patten does not follow this statement with a specific discussion as to his reasons, although his whole book is based on the principle of *increasing* returns.

I have looked through many books of modern writers on economics and find that all lay much emphasis on this law. The following are typical definitions from prominent economists. Seligman in his "Principles of Economics" says that "The law of diminishing returns is . . . the foundation of the law of rent. A farmer will some time reach a point where it will not pay him to add another laborer or another machine to his land because beyond the margin of profitable expenditure every additional 'dose' of capital or labor will mean a return insufficient to cover cost. . . . The law of diminishing returns is universal and applies to everything that possesses value." Professor Seager in his "Introduction to Economics" says, "After a certain point has been reached in the cultivation of an acre of land or exploitation of a mine increased applications of labor and capital yield less than proportionate returns in product, it being understood, of course, that no important change is

made in the method of cultivation or exploitation." Carver in his "Distribution of Wealth" goes more into detail and proves the law with mathematical exactness. In fact, he is so clear that he seems to be proving the obvious. However, he offers as an excuse that such proof would not be needed "had not certain writers seen fit to deny it because it did not harmonize with their views of economics, and certain would-be reformers to ignore it because its recognition would interfere with the acceptance of their reforms."

Such a reformer, I suppose, he would call Wm. H. Allen, of New York, who said in a recent article in the *Annals of The American Academy* that "When John D. Rockefeller said to the world, 'There will never be enough money to do the world's uplift work,' he started in motion forces and doubts and compromises that will do vastly more harm to the south than the hookworm." The reason Mr. Rockefeller made such a statement was that he was biased by the law of diminishing returns which closes the door of hope, because, as Patten indicates, hopelessness is inherent in a world of diminishing returns. Many who argue for the truth of this law quote not only men of success like Mr. Rockefeller, but any business man or farmer who finds himself face to face with the law. The difficulty in both cases is that the individual is looking at production from his personal point of view, and not from the point of view of production as a whole. The economists, however, ought to see principles in the large.

Scientific laws are much like creeds. Some one has an insight which he formulates, and for him and some of his successors the formulation seems to satisfy the conditions and the needs. So an economic law is the classification of a group of facts as some one's insight sees them; but as with the creed, men may make the fatal mistake of thinking it an eternal truth. There was a time when belief in hell fire was an incentive to morality, but now many of us succeed in getting a degree of morality when in the state of mind of the small son of a famous modern philosopher who asked his mother what hell was. She described it to him and at the close added, "But there are some who do not believe this." The boy replied, "Mamma, I am one of those." There was a time when the law under discussion had a vital meaning to the race, but I am one of those who think that a new formulation is in place, that here is a case where orthodoxy does not mean clear thinking.

The fallacy common to Seligman, Seager, Carver and the others is that of emphasizing archaic conditions. Seligman, for example, was talking about equal "additional doses" of capital and labor; and Seager at the close of his definition said, "it being understood, of course, that no important change is made in the method of cultivation or exploitation." Now of what earthly good is a law for such conditions? If

there is any indisputable fact in the world it is that important changes *are* being made in the methods of cultivation and exploitation, and as for *equal* "doses" of capital and labor, who is so simple as to think of adding them? The question is not that of adding another cartload of the old fertilizer to a wheat field, but of adding some new fertilizer, exactly fitted to the wants of the crop, by which it may be doubled in quantity. It is not a question of adding a man with a sickle, but of adding a man with a modern harvester; not of sowing the old seed to yield tenfold, but the new seed to yield an hundredfold. Capital is multiplying so rapidly that it worries some people, at least, to know what to "dose," and invention multiplies the units of labor so fast that they outstrip even our imagination. Now, to be sure, individual farmers must have practical methods of directing the expenditure of what capital and labor they have, and the law applies to them since an individual is more or less in an eddy, just as I am in the matter of capital. I have little more than I had before the last multiplication of the capital of the world, but I am not so personal as to deny the increase. I claim to be part of the age of airships, though I have never seen one, and am no nearer an automobile than a state of covetousness. I try not to be like the woman in a small town who came to me after a lecture in which I had said that, since three fourths of the women in that village bought their bread from bakeries where it was made by men, they could retain their power over bread making only by voting, she confidentially told me that she made her own bread, and hence did not see any need for women's voting. It seems to me that an economic law ought to be comprehensive enough to summarize the individual cases.

Professor Carver shows conclusively that in an individual case the law of diminishing returns may work exactly. He even shows that large-scale production does not overthrow the principle; but he does not consider the pertinent fact of modern industry, that invention, organization and efficiency make constantly changing conditions, and that "equal doses" are out of date. He admits that the law is more evident when applied to stationary civilization, saying, "*If* civilization should remain stationary while population increases in density there would be a smaller per capita production because of the law of diminishing returns. The terrible reality of this law is witnessed by the overcrowding of those populations where, as in the unchanging east, civilization has become stationary." I reply, "to be sure," but modern economics is neither history nor anthropology, and what should be taught in our colleges and to business men is a principle that applies to a progressive civilization. Again Carver says, "but with respect to the livelihood of a complex population considering all its industries in a mass, the operation of the law is not so clearly perceived."

Again I say, "to be sure," because under such conditions it is not operating. And at the end of his long chapter, considering the relative productiveness of different sorts of labor, he states, "that nothing could prevent its (the former of the cited classes of labor) declining relatively to that of the latter class except a radical change in the system of industry, which would call for more than a proportional increase in the former class." The contention of this article is that there has been this radical change in the system of industry, that increases are becoming more than proportional and that we are not yet even in sight of the beginning of the end. I am perfectly willing to admit that the law of diminishing returns has an illustrative value, but it is taught in many courses and economic articles as though the world in which we live were about to suffer from its "terrible reality" as it would in a world of stationary civilization. At a recent large gathering of economists there were but two expressed exceptions to the opinion that immigration was about to become dangerous because the additional numbers would make competition too keen. They thus implied the fear that this bugbear law of diminishing returns will soon deprive us of enough to eat. The whole difficulty is a mistaking of unjust and unequal distribution of wealth for an application of the law of diminishing returns. I presume that Mr. Rockefeller's difficulty arises from the fact that any other method of distribution than that which has been contributory to his own success is inconceivable. But economists ought to be able to see production and distribution at the same time and in their totality.

The law of diminishing returns is intimately related to another famous and equally archaic economic law, viz., Malthus's law of population. The substance of this law is that population tends to increase faster than the means of subsistence. There is something in this. It works in determining the number of wolves, but the last census report does not show *human* population in America confirming it. It is always a great satisfaction to find a single principle which will explain a condition; but we are becoming more and more convinced that social phenomena are the product of numerous forces and are not reducible to a single law. Malthus's law does not care whether a single family has many or few children, but whether population is increasing or decreasing. So the law of diminishing returns ought not to be limited to individual production, but extended to production as a whole. It is quite true that the surface of the earth is limited in extent, and that the population of the earth is multiplying; but it is likewise true that the sun is losing its heat, and that some time the earth will be uninhabitable. Any physicist might logically teach his classes the desirability that the human race accustom itself to the idea of being frozen

out. But whatever the logic of the question, it would and should make very little impression on the average healthy-minded individual. Our problem presents a very similar situation in which we may justly question whether a healthy-minded person should have any fear about the exhaustion of the proper number of food units that may be required, even if he is as far sighted as a conservation congress.

Soon after Malthus had written his book, his theory fell into disrepute because of the opening of the great interior plain of the United States. But thinkers soon saw that the principle was just as true as before, though the pressure of conditions was temporarily postponed. But now that we have come practically to the end of free land we seem to be nearer than ever to the threshold of the catastrophe. Even such a good thinker as Joseph L. Lee, the Boston philanthropist, feels it, for in speaking about immigration he says:

> America is not infinitely large. It will in any case—in what, compared with the long future, must be regarded as a very short time—become so crowded that any further increase of the population—except at a comparatively slow rate can be made only at the cost of lowering the general standard of prosperity.

Land, however, is only one of the three factors in production. The incalculable additions to labor and capital in the last generation are so much greater contributions than more land could be that we are getting farther and farther away from, rather than nearer to, the catastrophe. To return to the analogy of the sun's heat: it is of course true that the sun can not continue to give off heat forever and remain as hot as before. But we have an interesting condition arising from the fact that though the sun is radiating its heat and thus diminishing its potential energy, yet the process of contraction which is taking place within the sun causes it to generate heat as rapidly as it is losing it, and while this is not a perpetual-motion machine, for the purposes of giving continuity of heat to the earth it is a perfectly satisfactory arrangement.

In like manner it makes no difference whether we get more land, or more productivity from the same land. Malthus found that population tended to multiply by geometrical progression, while the means of subsistence multiplied by arithmetical progression. This is true so long as the process is on an "equal dose" basis. But the conspicuous fact of modern times is that means of subsistence are multiplying at a rate which makes the multiplication of population look like the pace of the historic tortoise compared to that of Achilles, whom logic tried to keep from catching up. The logic of the law of diminishing returns is of the same type. Professor Carver shows that on a certain area of land twenty men can produce more per man than fifty, though the total production of the twenty men is but 380 bushels compared with 650 bushels produced by the fifty men. As a matter of fact, in spite of Zeno's logic we know that Achilles could overtake the tortoise, and we

likewise know that the 650 bushels are being produced, and that everybody has more to eat than formerly. If pragmatism is justified anywhere it is in such considerations.

A farmer recently told me that his father paid for his farm, fifty years ago, by carrying the mail from Jackson to Grand Rapids, Mich., one hundred miles, taking just a week for the round trip. All the information he carried could now be transmitted by wire in three minutes and the increase in the amount now transmitted per man in the mail service per week is represented by a geometrical progression with a tremendous ratio. From this same farm his father hauled his wheat thirty-five miles to Jackson, taking approximately fifteen hundred pounds to the load, and requiring three days for the round trip. The Michigan Central freight can now transport wheat at least sixty thousand times faster; so that even though the most liberal division be made as to the part contributed by an equivalent of a single man and team now, a man's productivity is multiplied several thousand times. This is what we add instead of an "equal dose." It may be claimed, however, that the introduction of the railroad brought a period of phenomenal increasing returns, but that they were not maintained. It is a fact that there has not been an increase in speed at all in proportion to the outlay devoted to increasing speed, and the law of diminishing returns seems herein to be finely illustrated. However, increase in transportation does not mean simply increase in speed, but much more, it means number and extent of persons and things that can be transported in a given time. The number of people who have been brought into participation in transportation through the extension of the railroads, the increase in the power of locomotives, and the organization of the systems, demonstrates that the rate of progress has been continuous and of the same radical character as the change from stage-coach to express train. The exhibition of increasing returns is multifarious. During the Boer War I received the evening paper in an interior city at five thirty P.M. and read of battles that occurred at six o'clock that same afternoon in South Africa. This was in Tennessee near the home of Andrew Jackson who fought the battle of New Orleans after the war was over, and he did not then hear of peace until several weeks after it had been declared.

Increase in units of production does not consist merely of adding similar units. The saving of time by rapid transportation and intercommunication, the organization of capital so that it may be turned over several times where formerly it could perform but one service, makes a multiplication almost inconceivable, and every one knows that in the region of invention and organization we are just beginning to open up discoveries for entry; while the division of labor and the application of the processes of efficiency-engineering give a potentiality to the present units of labor that is revolutionary. If we will project our

imagination, keeping within the limits of reason, we can predict the rate of progress will be continuous. It is quite conceivable that before this generation is passed we shall plough with power generated by the tides and transmitted by wireless processes, and that radium will be harnessed so that its incalculable energy can be used. With the tremendous increase in power the surface of the earth can be enlarged indefinitely. Why should not the plains of Europe and America be set on edge, or why should not artificial heat and light make possible several layers of productive soil, and certainly it can be employed all the year round! Already sanitation and invention are making possible the exploitation of the tropics, the really productive regions of the earth which hitherto have been undeveloped. Men can soon work where they can not live continuously because they can commute in airships and change climatic conditions daily.

In the light of these facts and fancies let us consider the validity of Malthus's three principles:

1. "Population is necessarily limited by the means of subsistence." This is more imaginative than dangerous, for, since "means of subsistence" is psychological as well as physical, it can not become a mathematical term. Nowadays our magazines are telling us that consumption of one half or one third of the "means of subsistence" would add greatly to our efficiency. I myself have made a definite reduction in the amount of food consumed and thereby multiplied my efficiency. Furthermore, it is undoubted that the science of nutrition is going to add many units to the food supply by subtracting the injurious, the wasted, and the unnecessary. This is the prospect before us, but in the meantime, with all the natural forces for multiplication of population active, nevertheless the means of subsistence has increased far beyond any proportions that have before prevailed. There is not the slightest evidence to-day that means of subsistence is directly effecting the increase in population.

2. "Population invariably increases where the means of subsistence increases, unless prevented by very powerful and obvious checks." This is so untrue to-day that it is not open to argument. In fact, the portion of population having the greatest means of subsistence is standing still while the poorest furnishes the greatest increase. To be sure, the standard of life may be the line at which the force of the means of subsistence is defined, but this is an artificial line. The rate of increase is not lessened by any powerful and obvious check, and it is not beginning to keep up with the rate of increase of the means of subsistence. There never was a time when the world was as well fed as at the present.

3. "These checks and the checks which repress the superior power of population and keep its effects on a level with the means of subsistence are all resolvable into moral restraint, vice and misery." Professor

Patten in his last book, "The Social Basis of Religion," says, "Sin is misery; misery is poverty; the antidote of poverty is income." If the signs of the times meant anything, there is an increase in the world's income and a potential decrease in the world's misery through better distribution. Misery, then, with its accompanying vice can not be the result of the law of diminishing returns, for returns are increasing.

Since the means of production are land, labor and capital, and the methods of capitalistic-mechanical production increase the possibilities of the last two indefinitely, the resources of production show no more signs of being exhausted than the heat of the sun. Our census returns show that the population of the United States has increased 21 per cent. in the last decade, that urban population has increased even more, and that many of the best rural districts have lost population; and still there has been a disproportionate increase in the amount and variety of food. These facts make it absurd to argue that, as applied to production in the large, the law of diminishing returns is a factor to be considered. Why then in the teaching of economics, and in business is not the emphasis changed so that such a point of view as that of Mr. Rockefeller may not be attained? For obviously, as Patten says, our modern progressive civilization has passed the line of deficit and is capturing broader and broader fields of surplus. If we are going to retain a full treatment of this law and Malthusianism in our text-books, could it not be labeled as a historical condition of which occasional relics may still be found? In answer to the argument that it is essential that we take the law as a starting point for the explanation of economic phenomena, I would reply that the explanation is good only for a condition that is stationary and looks to the past. May we not demand that in some way economists should frame a law, in which, as in the law of the moving point by which the hyperbola is traced, the prophecy of the future should be as perfectly expressed as the history of the past, and thus looking ahead, give us a true description of modern conditions of production?

THE GERMANS AT SCHOOL

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AT the time of their political weakness the Germans were derisively called the thinkers and dreamers. When the other great nations divided the world of reality among themselves, the Germans took refuge in the realm of fancy. The stronger peoples considered them as the members of a rich household look on the poor schoolmaster at their table. That time has passed away. The politics and commerce and industry of Germany have secured its powerful position in the world, and no one doubts the strength of the Germans in the field of the real facts. But there was mingled with the derisive mood of previous times a silent respect for that German idealism. The name of thinkers and dreamers appeared to some, and not to the worst, a title of honor. The world acknowledged that in scholarship and research and education the Germans were able to teach mankind. Their schools were models and their methods superior, and in the days of war the world accepted the saying that the German schoolmaster had won the battles. How much of this honor and glory has been left in these days of German commercial, industrial and political advance? Has the forward striving in the realm of might and power meant loss of prestige, and, what is more important, loss of true achievement in the field of thought and education, or did the progress of modern Germany involve as much intellectual gain as practical profit? The Germans at work easily win the admiration of every visitor who goes to their centers of industry. Are the Germans at school equally deserving of honorable praise, or are they simply resting on their laurels?

The educational life of a country is always a great organism in which all parts are interdependent. There can not be good schools without good universities, nor good universities without good schools. The quality of the teachers and the quality of the pupils, the general education and the special instruction are all intimately related to one another. We must look into this organic system if we want to ascertain its strength and endurance. A few educational show pieces are not enough. Is there progress and growth in all the essential parts. We may begin with the German university, which is, after all, the real heart of the whole organism and which had more direct influence on American educational life than any other part of the German educational system. Those who built up the great American institutions in the last generation from mere colleges into true universities had received the decisive impulses in German academic halls. To be sure in recent years a kind

of reaction has set in in America. The tradition that German university work represents the highest standards of scholarship has recently been roughly handled by skeptics. Some have claimed that German university research is too specialistic and on that account too narrow. The German scholars lack the wide perspective which has been characteristic of so much of the best English work. Others insist that the structure of the German publications is formless. They long for the French polish and clearness. Some blame the German professors for a certain remoteness from life and feel that American scholarship will abolish this kind of "scholarship for scholars" and will again unite science and life. It was inevitable that such a reaction should occur. The young generation of American university instructors found a situation entirely different from that which their teachers had found some decades before. Great American universities had been built up in the meantime and had created a new spirit of scholarly independence which naturally took the turn of a slight opposition to the former masters. But such reactions are only passing moods. Those who know German scholarship to-day have no doubt that all these accusations never have had less justice than at present. Certainly German scholarship is specialistic, and there will never be any true scholarship which is not founded on specialistic work. Any thorough research must be specialistic, and research without thoroughness can never secure lasting results. But the work of the great German naturalists and historians has shown at all times the tendency to wide generalizations, and the present day perhaps more than the last half century is again filled with broad philosophical endeavor. Still more unfair is the often repeated cry against the formlessness of German scholarship. Not every doctor's thesis can be a thing of beauty, but perhaps there has never been a time in which the German language has been so shaped by aesthetic ideals. The German bookbinders were for a long while notorious for tasteless covers, but the general opinion in recent international exhibitions has been that now no country makes more beautiful bindings than Germany. This artistic improvement of the book is not confined to the cover. The content of the German book shows a literary finish in structure and style which ought not to be overlooked. Finally, as to the aloofness of German scholarship, the triumphs of modern German technique and medical therapy speak loudly enough of the comradeship between science and life. And how could it be otherwise in a country which has become so mark-hunting and practical. The best proof of the injustice of such accusations and attacks lies in the number of American students who still feel attracted by the German academic atmosphere in spite of the wonderful development of American higher institutions of learning.

Last winter there were three hundred American students in Ger-

man universities, and it must not be forgotten that these young men and women are not undergraduate college students, but that the German university welcomes them only if they can show their college diploma. The German semesters correspond to the study in the post-graduate departments of the American universities. As Director of the Amerika-Institut, I wrote to these three hundred delegates of the new world and asked them with what training they came and for what purpose, whether they felt satisfied or whether they found anything of which to complain, what they were doing and what they were intending to do, and what they could suggest. The answers display an interesting variety. The young American scholars came from all parts of the country and their favorite spots in Germany are Berlin, Leipzig, Munich, Heidelberg and Göttingen. In their studies naturally the German language and German literature take the lead, but philosophy, history, political economy and, in the line of science, chemistry and medicine stand next. Mathematics is also often chosen, and, on the whole, there is no corner in the field of learning to which some Americans are not turning. Lowest in the list is the study of law, which of course is best pursued in one's own country. As to their aims and reasons for coming to Germany, some, to be sure, had no deeper argument than that they "had a fellowship," and some that there "is no special reason." Some wanted to see a foreign civilization at first-hand in order to be able to judge more correctly of their own, or to study German in order to teach it in America. But the overwhelming majority insisted that there was still superior opportunity for their special branches in German institutions and that the most thorough and deepest preparation could still be gained on German soil. The two fundamental tones of the replies were given by the one who wrote: "I came to train myself to think independently," and by the other who wrote: "The best that was offered me in the American lecture room, library and seminary was the fruit directly or indirectly of German research. I wished to come into intimate contact with it." As to their satisfaction with the results, praise and complaint were intermingled. Many asserted that they were entirely satisfied, not a few expressing themselves in terms of enthusiasm. Some limited their approval to certain sides: "Very well satisfied with intellectual side of the university, but have not received much help religiously." Others miss the American sports or the social life among students. Many are dissatisfied with the lack of personal contact with professors. Again some complain that the student finds no oversight and is not called to account and that accordingly too much loafing is possible. Some complain that the attendants do not understand English or that the libraries do not give out the books quickly enough. Some suggest more opportunities for learning the language, others demand the removal of evil social influences and student drunk-

enness. But there is an almost surprising unity in the instinctive acknowledgment of the admirable methods of research and of highly advanced instruction. This cordial appreciation by those who stand in the midst of the German influences corresponds to the judgment of all who see German academic life with impartial eyes. There is an intensity in the search for truth and an eagerness for the development of the best scholarly methods which is still unsurpassed in the world.

The weaknesses of the German university are not few. To those who come from American traditions the most regrettable difference is the lack of interest in the student's life. The student is practically left to himself. This is true as to his social life and true as to his studies. No one supervises him, no one cares whether he is industrious or lazy, and the result is that many a weak man comes to grief who might have succeeded with the help and control of the American system. But these defects of the German university as educational institutions are the necessary counterparts of their excellencies as places of independent scholarship. The highest goal of intellectual achievement will always be reached only in complete freedom, and this freedom is somewhat dangerous for the weak man. There can be no doubt that the German system is indeed much more adjusted to those above the average than to those below, and the opposite is true of the American system. But it is not only the lack of personal help and the demand for his own activity which is in contrast with the American ample provisions for intellectual support. Even the choice of the teachers differs in the same direction. The American instructor is appointed, above all, because he is a good teacher; the German because he is an important contributor to the advancement of knowledge. He may be and not seldom is a poor teacher. Yet the German university ideal suggests that the true student will profit more from the contact with a man who has mastered the method of research than with any inferior scholar, however effective he may be as a teacher. The American is often no less surprised by the way in which the professors are chosen for appointment. The American universities are monarchies. The president with his trustees elects a new member of the faculty without being dependent upon the vote of any professor. In the democratic life of the German university the government which has to make the appointments is dependent upon the vote of the faculty itself. The professors choose their own colleagues. This again in principle indicates the desire to make the point of view of scholarship superior to every administrative question. It can not be denied that in practise it frequently looks quite differently. The influence of the colleagues is too often exerted in the interest of some groups, cliques and petty prejudices. It would be a blessing for many a university faculty in Germany if an American president with his great powers stood above them. The Ger-

mans themselves are far from considering their universities perfect. Intense reform movements are reshaping the entire university life, but it is characteristic that no so-called reform propositions are taking hold which limit in any way the freedom of study. The Germans do not want more examinations by which the student becomes more or less a school pupil, although they believe in thorough discipline and supervision even in the highest classes of the Gymnasium, which corresponds to the average American college. The most wholesome change in the student life is the quiet but steady repression of the vulgar beer-drinking habits with all the noisy accessories. The entire student life has become cleaner and more modern. The old traditions had come from a time when the young academic scholar wanted to emphasize the contrast between his eager life and the dullness of the philistine crowd. But modern times have changed this contrast by bringing life and interest and political activity into those crowds and the student has thus lost his right to live a life entirely different from that of his social surroundings. The rush of young Germany toward the university is still steadily increasing. There are about 63,000 students in the twenty-one high seats of learning, 12,000 in the law schools, 12,000 in the medical schools, about 4,000 students of divinity and the remainder in the so-called philosophical faculty which corresponds to the American graduate school. It is characteristic that the chief increase has come to the universities in the large cities in which the old-fashioned student life has always played a small rôle. In Berlin there are 14,000 persons attending the lectures and in Munich 7,000, in Leipzig 6,000. Yet especially those universities in small towns which are famous for the beauty of landscape have had their proportionate growth. In lovely Freiburg in Baden the one thousandth student was welcomed with a celebration at the time when I came there as a young instructor. Recently they have celebrated the coming of the three thousandth student. The rapid growth of the academic communities strongly suggests the foundation of new universities. Münster in Westphalia grew into a full-fledged university only a few years ago, Frankfort-on-Main is at present fighting with enthusiasm for the development of its academy into a university. The Prussian Diet is still seriously objecting to this ambition of the citizens of Frankfort, as it fears that the smaller universities in the neighborhood would be the sufferers, but the university of Frankfort is surely to come. The same may be said of the university of Hamburg, which so far consists of a number of interrelated institutes. But while the universities are growing in number and branching off in new and ever new specialties, they are also being supplemented by new forms of scholarly activity. The most characteristic new feature which gains increasing importance is the erection of research institutes, especially in the field of natural science and medicine. There investigations can

be carried on without any reference to instruction, the scholars are disburdened from every educational responsibility, and the progress of knowledge becomes the only goal. At the same time the number of technical schools on the level of the universities has been increased to twelve, since those of Danzig and Breslau have recently come into existence, and Germany's famous mining schools, forest schools, agricultural schools and veterinary schools show the same signs of flourishing life.

The greatest change, however, in the academic life of the nation has come through the new regulations which link the university with the schools. The American schools have usually left a certain freedom in the choice of studies within a single institution. In the same high school the boy can take a classical course or a more realistic course. Germany has always had separate schools for the different schemes of preparation. The higher schools which engaged the boys to the nineteenth or twentieth year have always been of three types, the Gymnasium which puts the chief emphasis on Latin and Greek, the Real gymnasium which omits the Greek and emphasizes modern languages and the Oberreal gymnasium which has very little Latin but much natural science. They correspond roughly to the American high school and a modest American college or the first two or three years of the best colleges. The tradition allowed only those who had the certificate of the Gymnasium to take up the study of law, medicine, divinity and philology. The university study of natural sciences and of modern languages besides a number of practical callings were the only goals accessible to those who came from the other two types of schools. Long struggles which excited all Germany led to the abolition of this monopoly by classical education. With the year 1902 the great modern school reform began and every year has brought new advance. To-day practically every boy who has passed through a school of any one of the three types finds the doors of the university wide open, whatever profession he may choose. It may be too early to judge whether only advantages will follow in the train of this reform. There are not a few who are afraid that the realistic schooling of the future lawyers and government officers may be a danger for the idealistic character of the national life, and there are many who believe that even the physician needs to read his Plato in school time more than to begin at once with the chemical laboratory. But in any case the great change has brought fresh air into the academic halls. The second great change was the full admission of women. For a long time they had the permission to attend lectures but no academic rights equal to those of men could be acknowledged for the women students until they should bring to the entrance door of the university the same certificate as the boys were expected to bring from their schools. The real advance of the women

in the university sphere depended upon the establishment of girls' schools which would lead to exactly the same goal as the Gymnasium for boys. This was at last accomplished by the splendid organization of girls' instruction of three years ago.

Prussia has now four types of higher schools for girls, each of which may be divided into various independent departments. In the center stands the upper girls' school, a somewhat revised edition of the traditional German school for girls. There are ten classes which are usually passed through in the period from the sixth to the sixteenth year. The first three classes are preparatory, with eight to ten hours a week instruction in the mother tongue, three hours arithmetic every week, two to three hours writing, two hours needlework, three hours of religion, which is an organic part of every German school, two half hours of singing, two half hours of gymnastics and some drawing as well. In the seven upper classes the German language takes six, five and finally four hours a week, and French exactly the same number, altogether thirty-two hours each in those seven years. English is taught in the four upper classes only four hours a week, mathematics three hours a week throughout, geography two hours through the seven years, natural history two hours, religion two hours, drawing two hours, singing two hours, gymnastic two hours, needlework two hours, but this is no longer obligatory in the four upper classes. Those who have passed through this ten years' course may enter either the so-called Frauenschule or the Seminary or the Studienanstalt. The first is planned to complete the education of a young woman who seeks a higher training without any professional aim. It is adjusted to the needs of women who are to play an intelligent rôle, not only in the home, but also in social life. It is in no way a finishing school for one who aims to shine in society, but meant for those who really want to serve. It is usually a course of two years in which pedagogy, household economy, kindergarten work, hygiene, political economy, civics, bookkeeping and needlework stand in the foreground, while modern languages, history, literature, natural science, art, drawing and music are relegated to the position of minor electives. The Seminary, on the other hand, is meant for those who aim to become teachers of the lower schools. It demands three years' scholarly work and one year of practical training in schools. In those three years of theoretical study, French, English and mathematics take four hours a week each year, German, natural science and religion three hours a week, pedagogy, history and geography two hours. In their fourth year, the practical term, the candidates study pedagogy and methods of teaching seven hours, eight hours a week thesis writing, six hours training in practical class work and six hours training in the practical methods of the various subjects, including laboratory experiments. In addition to all this, through the four years

there are three hours of gymnastics, two hours of drawing and one hour of singing. For the friends of women's progress, however, the chief accent of the system lies on the Studienanstalt. It is a school of six classes demanding six years' work open to those who have passed the first seven classes of the higher girls' schools. The three highest classes of the girls' school are then skipped, and instead of them the six years' course undertaken. This, however, is again divided into three separate schools corresponding to the Gymnasium, the Real gymnasium and the Oberrealschule of the boys. In the Gymnasium course during those six years the girls have three hours a week German, six hours a week Latin, at first three, later two hours French, in the first two classes three hours a week English, in the last four classes eight hours a week Greek. Through all the years there is history two hours, mathematics first four, later two hours, religion two, geography one, gymnastics three and drawing three. In the Real gymnasium the girls have no Greek whatever, but throughout six hours Latin, three hours French, three hours English and somewhat more mathematics and natural science than in the Gymnasium course. Finally in the Oberrealschule Latin too is omitted while both French and English are increased to four hours a week, mathematics to five, natural science to four and German also to four. This new plan adapts itself most successfully to the various needs, and the only danger lies in the fact that inasmuch as these three last types of schools open wide the way to the professional studies of the universities the number of academically trained women may soon by far surpass the demand of the community.

This vivid activity in the direction of liberal changes through governmental initiative does not exclude an abundance of efforts to break new educational paths. For instance much interest is centered nowadays on the so-called reform schools. They aim toward postponing the decision for a particular type of school as late as possible. The usual schools are different from the start. The classical schools begin with their Latin in the lowest classes. The reform school systems, of which the model was the city school system of Frankfort, have a common foundation for all schools, reminding one in this respect of the American principle. The much-discussed Frankfort plan in the first three classes gives to all the pupils in common five hours German, six hours French, two hours geography, five hours mathematics, two hours of natural science, two hours of writing, three to two hours of religion, three hours of gymnastics, two hours of drawing and two hours of singing. Only with the fourth class does the bifurcation begin. In the classical course the fourth class begins at once with ten hours Latin and the sixth class with eight hours of Greek, while in the realistic course the Latin is started in the fourth class, with eight hours going down to six, and the English begins in the sixth class with six hours.

There is still much distrust of this apparently very reasonable procedure. Every one feels that the momentous decision of the character of the education ought to be made at an age when the individual differences show more clearly than in the first years of school life, but the friends of the traditional Gymnasium are still convinced that a thorough classical training in accordance with the old German ideals ought to shape the mind of the youth in the characteristic way from a tender age. There the German school men still stand in the midst of passionate discussions.

But the intense pedagogical forward movement of the German people must not be studied only in the programs of the official schools. After all they represent the conservative aspect. The most progressive changes which would upset the traditions altogether are expressed in private institutions, usually the creations of enthusiastic idealists. They feel that there is a deep-lying antagonism between the claims of the official school and hundreds of thousands of hopes. Undoubtedly a large part of the nation is convinced that the whole school system is antiquated and too little adjusted to the needs of the new Germany. The schools still carry with them too much of that Germany which lived and thought but which was politically powerless and in the practical world helpless. The new German who does not look into the clouds but prefers to stand with both feet firm on the ground wants knowledge of natural science instead of languages, wants development toward national patriotism instead of religion in school, and wants civics instead of archeology. The center of it all is the firm demand that the youth be prepared for the national life with its social demands and its realistic energies. The character is to be developed still more than the intellect, and the mind is to be schooled for a time which overstrains a man unless he is trained for concentration. Of course much superficiality and pedagogical amateurishness are in play there. Especially the educational value of the natural sciences is still a very doubtful claim in the eyes of those who have really watched the outcome. But in this point too the serious reformers propose a fundamental change. They say that natural sciences are indeed without fundamental significance for the mind of the youth if the instruction means only a heaping up of information. In these days of rapid naturalistic progress the temptation is always great to bring the boy in contact with as many fields of positive knowledge as possible. But there is too much kaleidoscopic unrest in this superficial excitement of the intellect to bring any lasting gain. The new leaders therefore wish that knowledge be considered as unimportant and that the mastery of method and of naturalistic thinking alone be emphasized. The boys are to learn how to learn from nature. And in a corresponding way these groups of reformers wish to change the teaching of history. The children are not

to learn the facts but the methods to find out the true facts from various sources. They are to be brought into contact with the old reports by which the events of the past are transmitted. The knowledge of the languages ought to be gained by practise in conversation, the knowledge of the earth by wandering and living in nature.

This is typically combined in the much-admired institutions of Dr. Lietz, the so-called Landerziehungsheime, educational homes in the country. Lietz was a young enthusiastic teacher who was moved by the ideal of building up healthy, strong, joyful, energetic and judicial men who would be in sympathy with their fellow creatures and understand the needs of the common people, and yet who would be inspired by art and science and technique. He has created in the loveliest regions of Germany three national schools, for the youngest children between seven and twelve in Ilsenburg in the Hartz, the second in Haubinda in Thuringia for the boys between twelve and fifteen and the third in the castle of Bieberstein in the Rhön Mountains for boys between sixteen and twenty. All three places are far removed from the turmoil of the world, and the boys find there a most harmonious interconnection of intellectual training, handicraft work, agricultural activity, sport and inspiring social intercourse between teachers and pupils. It is a delight to see those happy youngsters under conditions in which their natural instincts for out-of-door life and for social companionship, for manual activity and for sport, are so wholesomely satisfied and at the same time where their intellectual development is secured by individualizing training in scholarly method. They learn really to love the literature and the history of their country and to become personally interested in the political and the economic structure of their nation. Their minds are opened to music and art, to religion and morality. Small groups of them undertake walking trips not only into the near neighborhood, but to far-distant parts of the fatherland in a simple camping style. Sometimes even long journeys to Egypt and elsewhere have been undertaken in the vacation time. Truly it is an ideal method to develop a healthy mind in a healthy body. Whether it will become the crystallization point for general educational changes in Germany is, however, more than doubtful. So far these reforms are in an uphill fight. They suffer from that which they feel as an unfairness, namely, from the fact that their schools must lead the boys to the same examinations which the regular school boys have to pass if the pupils are to go over to the university or to any other official career. This demands that in the last years much cramming be introduced and that features be forced on these new boy paradises which seem very foreign to their spirit. They demand, accordingly, new regulations which will give to the new types of schools more appropriate examinations as end points. As long as this is not granted, these schools remain

confined to narrow circles. But more important perhaps is the second fact. The Germans feel on the whole very unwilling to give their sons and daughters out of the house, if the education can possibly be obtained in the neighborhood. The system of the American academies and boarding schools is contrary to all German traditions. Especially in the large cities in which the Americans are most readily inclined to send their children away for the educational years, the Germans would least think of separating the youth from the home.

It may seem surprising to American observers that in the abundance of educational schemes which recent times have ripened in Germany nowhere has a serious movement toward coeducation been started. In a very modest way it has been forced on the communities in those places in which girls want to be prepared for the university but where no special Gymnasium classes for girls have been arranged. Just these exceptional cases however hasten the establishment of special Gymnasiums for women. The German community is decidedly unwilling to gather in one schoolroom boys and girls beyond the age of the elementary school. They do not object to the coeducational instruction of small children in rural schools. This is a frequent practise. Nor do they object to the comradeship of young men and women on the level of the highest university work. But in the broad period of the development of adolescence they believe in strict bieducation. Even when the material of study is the same, differentiation of method is demanded and German pedagogues decidedly object to women teachers for grown-up boys. The fact is that the new girls' school plans, even where they lead to exactly the same goal as the Gymnasium or the Realschule, distribute the material in a characteristically different way from the program of the boys' schools. They acknowledge the psychological laws of the different rhythm of the development of the two sexes. The well-known suggestion that the boys become refined and the girls strengthened through the presence of the other sex is the more powerless since the educators feel justified in reporting that even America, where the experiment has been tried most extensively, is in a stage of reaction against the coeducational enthusiasm.

Whoever looks at the free play of educational energies in Germany's social organism is probably most impressed by the strong activity outside of the regular day schools. Instruction for those who go to school because they have not yet entered a practical life work is furnished everywhere in the world, but no country shows such systematic educational planning for those who have left school and are at work in business or in factories, in agriculture or in any other calling. The splendid development which this type of pedagogical influence has found in recent times has been to a high degree due to a reaction against grave misuses in the past. In early times, to be sure, the boy who left the primary school was under the strict control of the master in the work-

shop or in the business. But the nineteenth century changed those paternalizing conditions and brought complete freedom. The result was a steadily growing insubordination and obstinacy, frivolous breaches of contracts and unreliability, together with a craving for enjoyment on the moral side, and a lack of careful training on the professional side. The community felt this inability to get hold of the boys who had left school as one of the most serious national dangers. In response to this need the continuation schools were founded which are to develop the youth after the school years in moral, practical and intellectual respects. The essential difference from all other schools lies of course in the fact that these take only a fraction of the boy's time in order not to interfere with his work. But they receive their real social background by the legal obligation of the employer to give to every boy the opportunity to attend these school classes. Compared with the general elementary school, the continuation school is professional, while the other is a humanistic school. On the other hand, compared with the real technical schools both lower and higher, it combines the technical instruction with general education. But, above all, the technical schools demand for some years the whole working time of the pupils, while the continuation schools are only supplementary to the chief business of the boy. The technical schools, such as for instance all the agricultural schools or the special industrial schools or the commercial schools, are strictly professional; the continuation schools are essentially educational. It may be said that even the technical element in them becomes subordinated to the aim of making a whole man and not only a skilful worker out of the boy who has left the school in his fourteenth year. The principle of this continuation school has conquered all Germany, but the realization of it looks very different in the various parts of the country. In some, the communities are forced by law to establish such schools, in other parts the towns are free to arrange them according to the local needs. On the whole this difference seems less important, as the continuation schools are flourishing wonderfully in some parts in which the laws give large freedom in the matter to the community. The point about which the discussion at present seems much more excited is the question whether the school teacher or the man of practical life, the master in the arts and crafts, the business man, the farmer, the industrial specialist, is to be the decisive factor. The men of the workshop complain that these schools become worthless as soon as the methods and the points of view of the school teacher control them, and the opposite party believes that the highest value is missed if the spirit of the factory and not that of the schoolroom enters into them.

As the continuation schools were to serve the needs of young people in many different walks of practical life, the schools themselves had to develop an almost unlimited manifoldness. A subtle adjustment to the local conditions as well as to the varieties of industry and trade had to

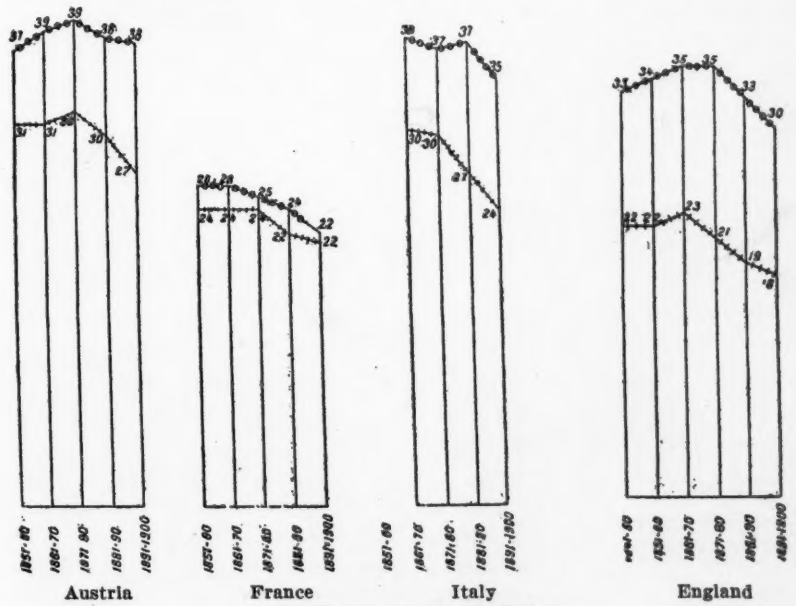
be aimed at. Continuation schools for candy makers and continuation schools for shoe makers had to be different. There are five chief types: the general continuation school, the commercial, the industrial, the rural and, exclusively for girls, the household economy school. Each of these types is realized sometimes in schools of obligatory character, and sometimes in schools where the attendance is voluntary, as well as in schools with prescribed courses, and in others with great freedom of election. The most famous system of continuation schools, the discussion of which has had most valuable influence on the whole German situation, is that of the city of Munich, where the indefatigable superintendent of schools, Dr. Kerschensteiner, has succeeded in a perfect adjustment of educational needs to the practical requirements of the community. Particularly his industrial continuation schools have been organized in such a way that almost every important business is represented by special classes for apprentices and special classes for journeymen and older working men. There are classes for chimney sweepers and for cabinetmakers, for coachmen and for ivory carvers, for watchmakers and for photographers, for tailors and for locksmiths, for barbers and for gardeners, for office boys and for waiters. There are altogether two hundred and ninety-six classes for the first years and one hundred and thirteen classes for those who are beyond the years of apprenticeship. About ten thousand boys are regularly attending. Every class has a careful program in which elements of general human education, elements of technical theoretical information and technical practical training, and finally elements of civic and sociological instruction, are harmoniously combined. This blending of different factors shows itself in the appointment of teachers. In the two hundred and ninety-six classes for the younger boys, for instance, we find seventy-seven general and thirty-seven technical teachers who devote to the work all their time and two hundred and twenty-one elementary-school teachers and one hundred and eleven technical and professional teachers who give instruction in their specialties as a side function, and one hundred and sixty teachers of religion. The essential point for an American spectator is, however, that the instruction for those thousands of young people in the midst of their practical life is given in the best hours of the day, either in the morning or in the afternoon, and that the employers are obliged to give them the opportunity to attend from six to ten hours a week for four years. Obligatory instruction in the evening when the young people come fatigued from their daily labor is excluded by the scheme. There is perhaps at present in the system of German school work no feature which so much deserves the attention of the American reformer as this whole plan of continuation schools as developed in the city of Munich and as more or less similarly organized in a large number of German cities.

THE PROGRESS OF SCIENCE

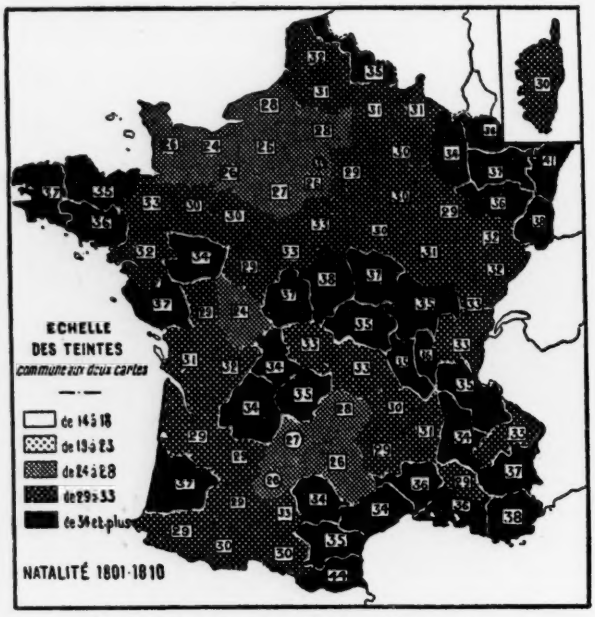
THE STATIONARY POPULATION OF FRANCE

GERMANY and France have happily settled their differences in regard to Morocco; but the German chancellor is charged in his own country with yielding not to France, but to Great Britain. France, which a hundred years ago lorded it over the Germanic nations and forty years ago believed that its military forces were superior to those of the German empire, has now almost lost its place among the great nations of Europe. Paris is nearly the same city it was forty years ago; Berlin is a new city. This alteration in the position of France is due to its stationary population. At the end of the last century the population of France formed one quarter of that of the civilized powers of the world, while at present it has fallen to seven per cent.

This state of affairs is causing much anxiety in France; it is discussed in detail in a recent book by Dr. Jacques Bertillon, chief of statistics for the city of Paris. The data which he reviews in detail deserve consideration not so much because, as he claims, they are peculiar to France, but rather because France has been first to exhibit a state of affairs likely soon to be evident everywhere. The charts here reproduced show the birth rates and death rates of four nations during the second half of the nineteenth century and the birth rates in the different regions of France for the first and last decades of the nineteenth century. It is almost incredible that there should be departments in which there are three deaths for every two births. In Lot the population has in the course of twenty years decreased from 271,514 to 216,611.



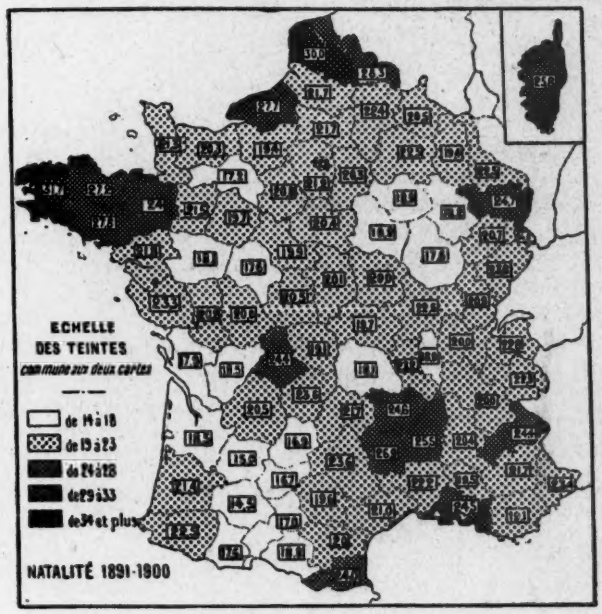
BIRTH RATES AND DEATH RATES.



BIRTH RATES IN THE FRENCH DEPARTMENTS

Every nation except France is increasing in population; but the birth rate is decreasing everywhere. Statistics can be misapplied to almost any purpose. Thus since 1876 the birth rate for France has decreased from 25 to 21 per thousand, whereas for England it has decreased from 36 to 27, and it might be alleged that, should the same decrease continue, the birth rate after an equal period would be about the same for France and England, and about a hundred years thereafter would be 5 in France and less than nothing in England. This is obviously absurd, but it is by no means unlikely that the birth rate will fall below the death rate in all civilized nations and later in other nations as they are brought within the circle of European civilization.

The increase in population during recent years has been due to the decreased death rate. This has resulted directly from the applications of science to medicine and hygiene and indirectly from the improved conditions of living which science has made possible. In all civilized countries the birth rate is now smaller than the death rate was formerly. But the death rate can not decrease indefinitely; it has indeed possibly reached in Great Britain a lower level than can be maintained. A death rate of 16 per thousand in a stationary population means that the average length of life is over 60 years and as one fourth of those who die are under five years of age the average age at death of those surviving infancy would be about 80 years. Odd as it may appear at first sight the decreased death rate of a country such as Great Britain is largely due to a decreasing birth rate combined with an increasing population. Such conditions give a population in which there are fewer children under five and fewer old people over sixty, in which groups the death rate is about 60 per thousand, whereas between the ages of 5 and 35 it is below 5. In France there are fewer children than have ever existed in any population, which reduces the death rate; but there are more old people—twice as many as in Great Britain—which increases it. The proportion of old people will further increase in France,



AT THE BEGINNING AND END OF THE NINETEENTH CENTURY.

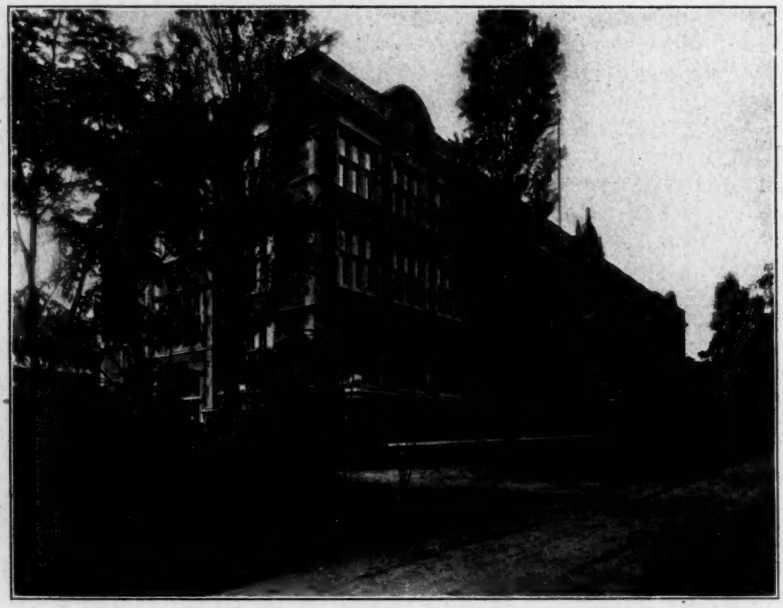
and will be tripled in Great Britain. It should also be remembered that the death rate of those over 45 has increased continually, owing mainly to the keeping alive of weakly people at earlier ages.

It seems unlikely that the death rate will ever be considerably smaller than it now is in England, whereas the conditions which have lowered the birth rate seem destined not only to continue but to increase. The physiological limitations will doubtless increase as children grow up who could not be born naturally or be nursed naturally or live through the harsher conditions that formerly obtained. The economic and social causes—the increase and wider diffusion of wealth, prudence and knowledge—will almost surely become more potent.

Dr. Bertillon discusses in detail the causes of the depopulation of France and the measures which he recommends to arrest it. The latter are indeed feeble in comparison with the former, and he puts on his title page the pessimistic motto "Il n'est pas besoin d'espérer pour entrependre ni de réussir pour persévérer." Apart from a moral regeneration leading people to want to do what they can rather than to get what they can, the remedy is in the direction recommended in the book, but requires far more radical measures. Children are no longer a financial asset to their parents, but they are this to the state and to the world; the state must ultimately pay for their birth and rearing.

THE ZOOLOGICAL LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA

FOUR of the leading eastern universities—Pennsylvania, Johns Hopkins, Princeton and Yale—have provided new laboratories for their departments of zoology. At the Johns Hopkins the laboratory is part of buildings planned for the whole university on its removal to a new site. At Princeton great buildings have been erected for the natural sciences and for physics, and similar buildings are in course of erection for Yale. The new building at the



ZOOLOGICAL LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA.

University of Pennsylvania, shown in the accompanying illustration, is the largest and best equipped building in this country, if not in the world, devoted wholly to zoology.

The architecture is of early English Renaissance, with walls of red brick in a variety of shades trimmed with Indiana limestone. The front façade, facing the north, is 216 feet in length; the south wing connects with the vivarium erected in 1900. The form of the building and the large windows give ample light to all rooms. Excellent as are the architectural effects they have in all cases been adjusted to the needs of the scientific work. The unit system of construction has been followed, so that rooms are of standard size and partitions can be readily added or removed.

The large lecture room seats 327 students and the smaller sixty, while the laboratories may also be used for lectures. Ample space is provided for the library and for a synoptical museum, but duplication of the exhibition museums of the Academy of Natural Sciences was wisely avoided. The elementary work is confined to the first floor, with four laboratories for general zoology, leaving the two upper floors for advanced work and research. The basement contains rooms for breeding, constant temperature, photography and other purposes, the heat and light being supplied from a central station.

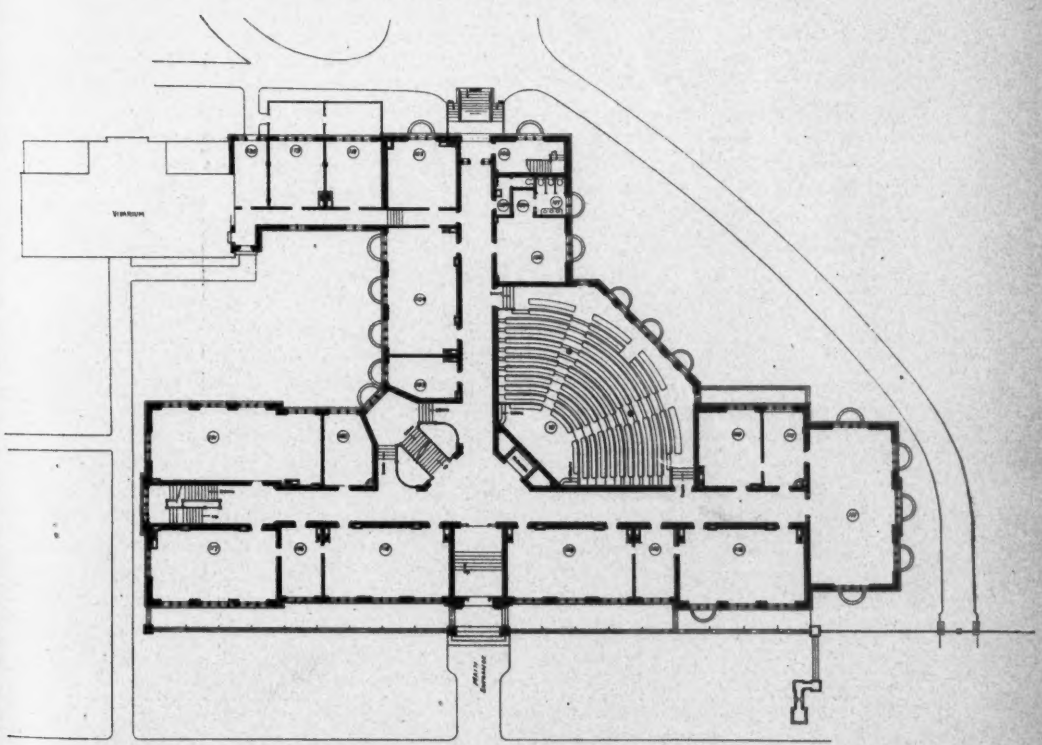
The United States would make unparalleled contributions to the advancement of science if these follow in proportion to the material equipment of its universities and government bureaus. But men are more important than their tools. It happens that of the great universities of the Atlantic seaboard the two—Harvard and Columbia—which lead all others in their zoological work are the only ones not having new laboratories. They will doubtless soon have them, but how much their investigations will be aided by the building, equipment and care of new laboratories is an open question. At Pennsylvania there is only one full professor of zoology. The interest on the cost of the building and grounds and the charge

for care and depreciation is much larger than the salaries paid to the teachers and investigators who occupy the building. The writer has good reason to remember well the old Biological Hall of the University of Pennsylvania. It cost perhaps $30,000; it was likely not only to burn down but to tumble down. Yet in that building some twenty years ago worked Leidy, Cope and Ryder, with two other professors in the zoological sciences, two professors of botany and a professor of psychology, all actively engaged in research work. Our universities doubtless need big buildings, but the need of great men is far more urgent.

SCIENTIFIC ITEMS

WE record with regret the deaths of the Rev. Henry C. McCook, of Philadelphia, known for his publications on popular entomology; of M. Louis-Joseph Troost, the eminent French chemist; of Professor August Michel-Levy, the distinguished French geologist; of M. Alfred Binet, director of the psychological laboratory of the University of Paris; of Dr. Wilhelm Dilthey, formerly professor of philosophy in the University of Berlin; of Dr. J. Hughlings-Jackson, F.R.S., eminent English neurologist, and of Professor Florentino Ameghino, the well-known paleontologist and director of the Museo Nacional in Buenos Aires.

MR. ANDREW CARNEGIE has given $25,000,000 to the Carnegie Corporation of New York, incorporated by the legislatiure last June. The objects of the corporation are "receiving and maintaining a fund or funds and applying the income thereof to promote the advancement and diffusion of knowledge and understanding among the people of the United States, by



PLAN OF THE FIRST FLOOR OF THE ZOOLOGICAL LABORATORY OF THE UNIVERSITY OF PENNSYLVANIA.

aiding technical schools, institutions of higher learning, libraries, scientific research, hero funds, useful publications, and by such other means as shall from time to time be found appropriate therefor."

BY the will of Mr. Joseph Pulitzer the million dollars which he had set aside for a School of Journalism at Columbia University is released, and the promise of an additional million on condition that the school be successfully conducted for three years is confirmed. $250,000 is bequeathed to Columbia University to continue the special scholarships for students of the New York public schools. $500,000 is bequeathed to the Metropolitan Museum of Art and an equal sum to the Philharmonic Society of New York. The income to be paid to two of his sons is limited until they have reached the age of thirty, and the balance is to be divided between Columbia University, the Metropolitan Museum of Art and the Philharmonic Society. This amount may apparently exceed $500,000 annually.

THE will of Miss Emma Carola Woerishoffer leaves $750,000 to the trustees of Bryn Mawr College, of which she was a recent graduate.

THE estate of John S. Kennedy is even larger than has been previously announced. The share of Columbia University is $2,429,943. The New York Public Library receives $2,779,790; the Metropolitan Museum of Art, $2,929,943; the Presbyterian Hospital, $1,514,086; New York University and the Presbyterian Board of Aid for Colleges, each $976,647; Robert College, Constantinople, $1,847,295. The specific bequests, not dependent on the size of the size of the estate, include $100,000 each to Yale, Amherst, Dartmouth, Bowdoin, Hamilton and Glasgow.

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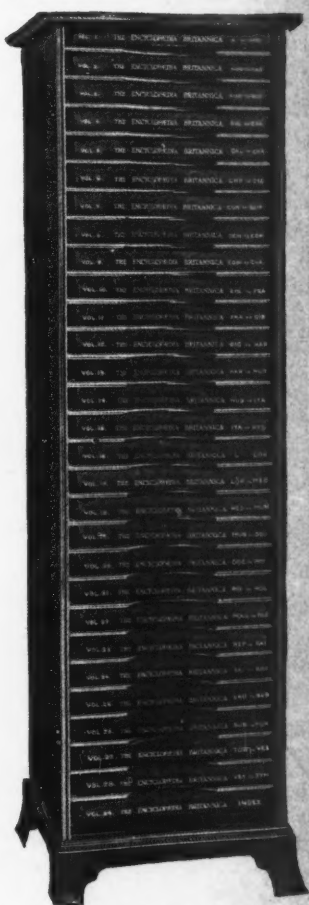

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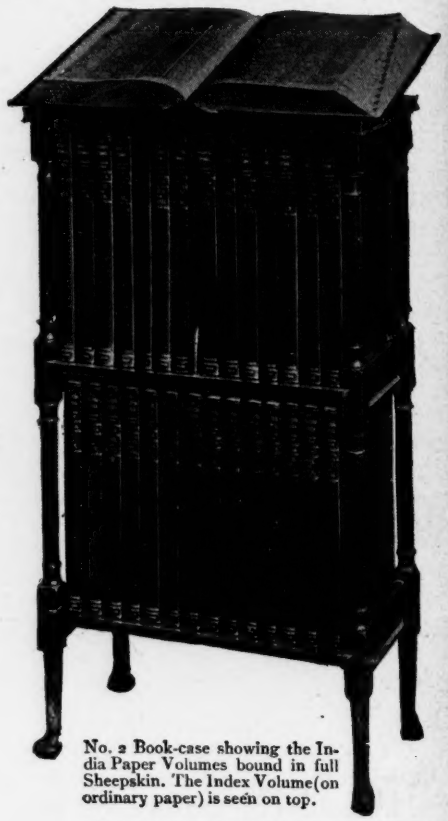

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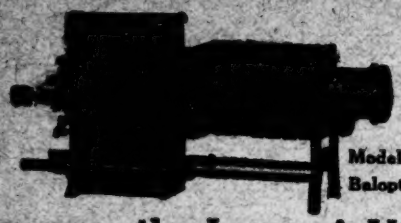

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